Biological efficacy performance evaluation of Ballast Water Management System in shipboard test

RayClean

DESMI Ocean Guard A/S

Final report

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The expert in **WATER ENVIRONMENTS**

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RayClean

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Abbreviations

Abbreviation	Description
AVG	Average
BE	Biological efficacy
BWMS	Ballast water management system
CFU	Colony-forming units
CMFDA	Chloromethylfluorescein diacetate
DOC	Dissolved organic carbon
DNV GL	Det Norske Veritas and Germanischer Lloyd
DPM	Disintegrations per minute
ETV	US-EPA, Environmental Technology Verification Program
FDA	Fluorescein diacetate
FR	Field replicate
IMO	International Maritime Organization
MEPC	Marine Environment Protection Committee
MM	Mineral materials
MPN	Most probable number
M/V	Motor vessel
NTU	Nephelometric turbidity units
POC	Particulate organic carbon
PSU	Practical salinity units
QAPP	Quality assurance project plan
QMP	Quality management plan
SOP	Standard operating procedure
STD	Standard deviation
TSS	Total suspended solids
UV	Ultraviolet
UV-I	UV intensity
UV-T	UV transmittance

1 Executive summary and conclusion

DHI provides independent biological performance evaluation of ballast water management systems (BWMS) for the type approval process. The purpose of the performance evaluation is to assure that BWMS approved by administrations are capable of meeting the ballast water discharge standard in Regulation D-2 /1/, also known as the IMO D-2 standard, in land-based and shipboard evaluations and do not cause unacceptable harm to the vessel, crew, environment or public health. The United States Coast Guard Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters /2/ (§151.2030) establish a ballast water discharge standard similar to the IMO D-2 standard. According to the U.S. Coast Guard, sampling and analyses for living organisms in shipboard performance evaluation of BWMS is to be conducted as described in the ETV protocol /3/.

The objective of this project was to conduct a shipboard performance evaluation of the DESMI Ocean Guard A/S BWMS RayClean with the aim to meet the U.S. Coast Guard Standards /2/ and the testing requirements in Resolution MEPC.174(58) /4/, generally referred to as IMO G8 guidelines. From June 2013 through January 2014, DHI conducted a shipboard test of RayClean BWMS with DNV GL as classification society.

A total of five biological efficacy (BE) test cycles were conducted on board M/V Thurø Mærsk. RayClean was operated by the vessel crew during all BE test cycles. DHI collected information relevant for the BE test cycles, and recorded operational observations when DHI staff was present during BE testing. DHI staff members were only present on the vessel during the BE test cycles and did not witness scheduled and unscheduled system maintenance performed on RayClean during the shipboard testing period.

In test cycles Nos.1 to 3, ballast and de-ballast operations were conducted while the vessel was moored at the Alcântara Container Terminal in the port of Lisbon, Portugal. Test cycle No. 1 was conducted in June 2013 and test cycles Nos. 2 and 3 were conducted in November 2013. In test cycles Nos. 4 and 5, ballast operations were conducted while the vessel was moored at Porto Grande, Cape Verde, and de-ballast operations were conducted while the vessel was moored at Porto da Praia, Cape Verde. Test cycles Nos. 4 and 5 were conducted in January 2014. The holding time varied from approx. 5 to 47 hours for treated water and from 5 to 49 hours for control water. RayClean was tested at salinities ranging from 30 to 37 practical salinity units (PSU) with water temperatures ranging from approx. 17 to 23°C. Table 1.1 summarizes the dates and locations of the shipboard test cycles.

Table 1.1 Dates and locations for RayClean shipboard test cycles

Test cycle	Location	Operation	Inlet	Discharge
No. 1*	Alcântara Container Terminal, Port of Lisbon, Portugal	Control	2013.06.25 15:45-16:50	2013.06.25 21:24-22:01
		BWMS	2013.06.25 18:12-19:33	2013.06.26 00:24-00:45 01:00-01:22***
No. 2*	Alcântara Container Terminal, Port of Lisbon, Portugal	Control	2013.11.01 20:01-21:12	2013.11.03 12:40-13:26
		BWMS	2013.11.01 16:42-19:23	2013.11.03 09:04-09:52
No. 3*	Alcântara Container Terminal, Port of Lisbon, Portugal	Control	2013.11.01 20:01-21:12	2013.11.03 12:40-13:26
		BWMS	2013.11.01 21:33-23:23	2013.11.03 14:01-14:47
No. 4**	Porto Grande; Mindelo, Cape Verde	Control	2014.01.27 14:26-15:50	2014.01.29 16:52-17:12
		BWMS	2014.01.27 16:49-18:24	2014.01.29 15:58-16:39
No. 5**	Porto Grande; Mindelo, Cape Verde	Control	2014.01.27 19:30-20:56	2014.01.29 22:10-22:31
		BWMS	2014.01.27 21:01-22:18	2014.01.29 20:53-21:36

* Dates and times according to local time at location (GMT +0)
** Dates and times according to local time at location (GMT -1)
*** Deballast operation was interrupted for 15 minutes due to water in an electrical socket caused by a leaking DHI sampling unit.

Samples were processed on board within the shortest possible time period. Samples for the enumeration of viable organisms ≥50 µm were analysed on board, and, for treated discharge samples, the total volume of each of the field replicates was analysed. Discharge samples for the enumeration of viable organisms in the ≥10 and <50 µm size class were transported to DHI Environmental Laboratory in Denmark, where analyses were initiated within 63 hours from sampling. Data for inlet water temperatures during BE test cycles, average sample temperatures during storage and transportation and time from sampling to analyses of organisms ≥10 and <50 µm in the discharge water are presented in Table 1.2. Detailed data for sample temperature logging during storage and transportation are available in Appendix 4, Tables A.4.1.1-A.4.1.5.

Table 1.2 Water temperature, temperature logging during storage and transportation and time from sampling to analyses of organisms ≥10 and <50 µm for control and treated discharge water samples

Test cycle	Analyses of organisms ≥10 and <50 µm in discharge water	Inlet water (°C)	Storage on location (°C)	Shipment to DHI (°C)	Storage at DHI Environmental laboratory (°C)	Time from sampling to analyses/ incubation
No. 1	Microscopy (CMFDA/FDA)	17	7.4	15	4.0	30 hours
	Re-growth				Not stored	25 hours
No. 2	Microscopy (CMFDA/FDA)	19	2.4	9.7	Not stored	34 hours
	Re-growth				Not stored	36 hours
No. 3	Microscopy (CMFDA/FDA)	19	2.4	9.7	Not stored	29 hours
	Re-growth				Not stored	31 hours
No. 4	Microscopy (CMFDA/FDA)	22	5.8	10	4.0	63 hours
	Re-growth				Not stored	53 hours
No. 5	Microscopy (CMFDA/FDA)	22	5.8	10	4.0	58 hours
	Re-growth				Not stored	48 hours

The densities of viable organisms from the ≥50 µm size class identified in the inlet and control discharge water were in accordance with the IMO G8 guidelines /4/ and the U.S. Coast Guard requirements in all test cycles. In test cycles Nos. 1-5, the average densities of viable organisms ≥50 µm ranged from approx. 5,500 to 92,000 organisms/m^3 in the inlet water, and from approx. 1,000 to 71,700 organisms/m^3 in the control discharge water. The densities of viable organisms from the ≥10 and <50 µm size class in the inlet water were in accordance with the requirement in the IMO G8 guidelines and the ETV protocol in all test cycles, except for a minor deviation in test cycles Nos. 2 and 3, in which the average number of viable organisms in the ≥10 and <50 µm size class was determined to be 99 organisms/mL with a standard deviation of ±1.0 (instead of ≥100 organisms/mL). This difference is considered negligible and without influence on the results. Furthermore, in the control discharge water from test cycles No. 2 and 3 the average density of viable organisms in the ≥10 and <50 µm size class was determined to be 106 organisms/mL. The average density of 99 organisms/mL in the inlet water from test cycles Nos. 2 and 3 was accepted by DNV GL in an email dated 19 November 2013 as meeting the requirement for a valid test cycle. In test cycles Nos. 1, 4 and 5, the average densities of viable organisms ≥10 and <50 µm in the inlet water varied from 131 to 375 organisms/mL when determined by inverted microscopy. Densities of viable organisms from the ≥10 and <50 µm size class in the control discharge water were in accordance with the IMO G8 guidelines and the ETV protocol in all test cycles. In the control discharge water in test cycles Nos. 1, 4 and 5, the average densities of viable organisms ranged from 16 to 149 organisms/mL when determined by microscopic analyses of chloromethylfluorescein diacetate/fluorescein diacetate (CMFDA/FDA) stained samples.

Table 1.3 summarizes the flow rates, UV transmittance (UV-T), UV intensity (UV-I) during ballast operations and the average numbers of viable organisms at discharge in water treated by RayClean. The viable organisms in the ≥10 and <50 µm size class were quantified by algal re-growth and addition of motile organisms without chlorophyll. DHI considers this quantification, which is also referred to as the most probable number of proliferating algae and addition of CMFDA/FDA-stained motile organisms without chlorophyll, the best available technique to determine viable organisms in the ≥10 and <50 µm size class after UV treatment. These stains react with non-specific esterases and intact stained cells fluoresce under the microscope. UV radiation causes damage to the cell DNA and prevents cell proliferation, but the esterase enzyme activity and the cell membrane may stay intact for several days. Table 1.4 summarizes the numbers of viable organisms in the ≥10 and <50 µm size class obtained by microscopic counting after staining with CMFDA and FDA.

Table 1.3 Average flow rates, UV-T and UV-I during ballast operation and average numbers (three replicates) of viable organisms in treated water at discharge. Viable organisms ≥10 and <50 µm were quantified by the most probable number of proliferating algae and addition of CMFDA/FDA-stained motile organisms without chlorophyll

Test cycle	Average flow rate during ballast operation		UV-T (%)	UV-I (W/m^2)**	Organisms ≥50 µm per m^3	Organisms ≥10 and <50 µm per mL; Algal re-growth*** + CMFDA/FDA-stained motile organisms	Organisms <10 µm Enterococci (CFU/100 mL)	Organisms <10 µm *E. coli* (CFU/100 mL)	Organisms <10 µm *V. cholerae* (CFU/100 mL)
	Treated (m^3/h)	Control (m^3/h)*							
No. 1	211	252	70	88-137	5.2	0.44	<10	<10	Absent
No. 2	195	315	53	40-205	9.4	0.35	<10	37	Absent
No. 3	221	315	71	61-230	1.9	0.28	<10	<10	Absent
No. 4	294	286	96	500	0	0.19	<10	107	Absent
No. 5	294	273	92	500	0	<0.18	<10	<10	Absent

* Volume recording and associated flow rate based on the vessel's ballast tank level gauging system. Recordings may be uncertain as a result of heeling of the vessel.
** UV-I reading at stable operating conditions
*** Algal taxa and species confirmed able to grow under the conditions in the re-growth assay (per cent of the taxa and species identified in the inlet water of the respective test cycles).
CFU Colony-forming units

Colours:
Green Compliance with the ballast water discharge standard
Red No compliance with the ballast water discharge standard

Table 1.4 Average numbers (three replicates) of viable organisms ≥10 and <50 µm in treated water at discharge quantified by microscopic counting after staining with CMFDA and FDA.

Test cycle	Organisms ≥10 and <50 µm Microscopy after CMFDA/FDA staining (organisms/mL)
No. 1	5.0
No. 2	4.5
No. 3	2.3
No. 4	0.83
No. 5	0.42

The performance evaluation based on algal re-growth and addition of motile organisms without chlorophyll for the organisms ≥10 and <50 µm (Table 1.3) leads to the conclusion that the RayClean BWMS complied with the ballast water discharge standard in all test cycles. This evaluation is further supported by CMFDA/FDA microscopic enumeration of organisms ≥10 and <50 µm (Table 1.4).

The trial period for shipboard testing started when the first valid and successful test cycle, test cycle No. 1, was performed during June 2013. The following four test cycles (test cycles Nos. 2, 3, 4 and 5) were also valid and successful. Thus, the treated ballast water at discharge was in compliance with Regulation D-2 /1/ for five consecutive and valid test cycles. Test cycle No. 5 was conducted in January 2014, seven months after the start of the shipboard trial period. Thus, the requirement of at least six months operation period of the BWMS for conduction of test cycles for biological efficacy performance evaluation was fulfilled. Based on shipboard test cycles Nos. 1 through 5, it can be concluded that efficacy of RayClean was in accordance with the requirements in the IMO G8 guidelines /4/ and complies with the U.S. Coast Guard Standards /2/ that prescribe confirmed efficacy of the BWMS according to the ballast water discharge standard during at least five consecutive valid test cycles.

2 Introduction

DHI is an independent, international consulting and research organisation established in Denmark and today represented in all regions of the world with a total of more than 1,000 employees. Our objectives are to advance technological development, governance and competence in the fields of water, environment and health. DHI works with governmental agencies and authorities, contractors, consultants and numerous industries.

DHI provides independent performance evaluation of ballast water management systems (BWMS) for the approval process. DHI has no involvement, intellectual or financial, in the mechanics, design or marketing of the products and technologies that are being evaluated. To ensure that DHI's tests are uncompromised by any real or perceived individual or team bias relative to test outcomes, DHI's test activities are subject to rigorous quality assurance (QA), quality control (QC) and documentation. DHI's quality management system is certified according to ISO 9001 by DNV GL. The certification is facilitated by the implementation of the DHI Business Management System.

The objective of this project was to conduct a shipboard performance evaluation of RayClean with the aim to meet the U.S. Coast Guard Standards /2/ and the testing requirements in Resolution MEPC.174(58) /4/, generally referred to as IMO G8 guidelines. According to the U.S. Coast Guard, sampling and analyses for living organisms in shipboard performance evaluation of BWMS shall be conducted as described in the ETV protocol /3/.

3 Classification society

The classification society appointed by the manufacturer for inspection and certification of the project is:

DNV GL
Veritasveien 1
NO-1363 Høvik
Norway

4 Client

The client requesting the performance evaluation is:

DESMI Ocean Guard A/S
Lufthavnsvej 12
DK-9400 Nørresundby
Denmark

The client is the manufacturer of the RayClean BWMS.

5 Testing laboratory

DHI Denmark was recognized as a sub-laboratory to the Independent Laboratory headed by DNV GL by Letter of Acceptance from U.S. Coast Guard dated 11 June 2013. DHI's Environmental Laboratory has an accreditation according to ISO 17025, which includes ecotoxicological studies and analyses related to performance evaluation of BWMS. Furthermore, the laboratory is authorized to carry out ecotoxicological studies in compliance with the OECD Principles of Good Laboratory Practice (GLP).

DHI's Environmental Laboratory and staff analysed all samples collected during the performance evaluation of BWMS.

The shipboard test was carried out by:

DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark

6 Ballast water management system

The BWMS examined in this performance evaluation was the DESMI Ocean Guard BWMS RayClean. The basic treatment principles of RayClean are mechanical filtration and UV disinfection. Mechanical filtration and UV disinfection were applied both during ballast and de-ballast operations. The maximum total rated capacity of the RayClean BWMS installation in the shipboard test was 300 m^3/h. The BWMS operated at maximum capacity as long as the measured UV intensity inside the UV disinfection unit was higher than 165 W/m^2. When UV intensities below 165 W/m^2 were recorded the flow rate was automatically reduced to maintain a minimum UV dose. A description of RayClean BWMS for shipboard testing was enclosed in Appendix C of the Test Plan (Appendix 1 in this report).

6.1 Performance claim and BWMS limitations

Before shipboard testing was initiated, DESMI Ocean Guard described a technology performance claim including limitations for treatment performance of RayClean, which was included in Section 4.1 of the Test Plan (Appendix 1).

7 Experimental design

7.1 Trial periods and locations

The shipboard test was conducted on board the container vessel Thurø Mærsk (IMO 8819976), registered in Denmark. Thurø Mærsk was built in 1991, and has a deadweight tonnage of 21,825 with a cargo capacity of 1,367 TEU (twenty foot equivalent unit). During the shipboard trial period the vessel was in regular route, where it typically called ports in Algeciras, Vigo, Leixoes and Lisbon on the Iberian Peninsula and a number of ports on the West African coast and in the Republic of Cape Verde.

The RayClean BWMS was installed in a container placed in the bottom of the cargo bay and connected to the ballast water system of the vessel.

Table 7.1 Details for inlet and discharge operations for shipboard test cycles. Detailed data logging information for each test cycle is available in Appendix 2.

Test cycle	Location	Operation	Inlet			Discharge		
			Date & time	UVI (W/m^2)	Volume & flow rate	Date & time	UVI (W/m^2)	Volume & flow rate
No. 1*	Alcântara Container Terminal, Port of Lisbon, Portugal	Control***	2013.06.25 15:45-16:50	-	273 m^3 252 m^3/h	2013.06.25 21:24-22:01	-	137 m^3 222 m^3/h
		BWMS****	2013.06.25 18:12-19:33	88-137	285 m^3 211 m^3/h	2013.06.26 00:24-00:45; 01:00-01:22	128-134	171 m^3 239 m^3/h
No. 2*	Alcântara Container Terminal, Port of Lisbon, Portugal	Control***	2013.11.01 20:01-21:12	-	373 m^3 315 m^3/h	2013.11.03 12:40-13:26	-	201 m^3 262 m^3/h
		BWMS	2013.11.01 16:42-19:23	40-205	523 m^3 195 m^3/h	2013.11.03 09:04-09:52	200-282	227 m^3 284 m^3/h
No. 3*	Alcântara Container Terminal, Port of Lisbon, Portugal	Control***	2013.11.01 20:01-21:12	-	373 m^3 315 m^3/h	2013.11.03 12:40-13:26	-	201 m^3 262 m^3/h
		BWMS	2013.11.01 21:33-23:23	61-230	405 m^3 221 m^3/h	2013.11.03 14:01-14:47	156-208	223 m^3 291 m^3/h
No. 4**	Ballast operation in Porto Grande, Mindelo, Cape Verde De-ballast operation in Porto da Praia, Praia, Cape Verde	Control***	2014.01.27 14:26-15:50	-	400 m^3 286 m^3/h	2014.01.29 16:52-17:12	-	127 m^3 381 m^3/h
		BWMS	2014.01.27 16:49-18:24	500	465 m^3 294 m^3/h	2014.01.29 15:58-16:39	500	186 m^3 272 m^3/h
No. 5**	Ballast operation in Porto Grande, Mindelo, Cape Verde De-ballast operation in Porto da Praia, Praia, Cape Verde	Control***	2014.01.27 19:30-20:56	-	391 m^3 273 m^3/h	2014.01.29 22:10-22:31	-	146 m^3 417 m^3/h
		BWMS	2014.01.27 21:01-22:18	500	377 m^3 294 m^3/h	2014.01.29 20:53-21:36	500	180 m^3 251 m^3/h

* Dates and times according to local time at location (GMT +0)
** Dates and times according to local time at location (GMT -1)
*** Volume recording and associated flow rate based on the vessel's ballast tank level gauging system. Recordings may be uncertain as a result of heeling of the vessel.
**** De-ballast operation was interrupted for 15 minutes due to water in an electrical socket caused by a leaking DHI sampling unit.

In test cycle No. 1, ballast and de-ballast operations were conducted while the vessel was moored at the Alcântara Container Terminal in the Port of Lisbon, Portugal, on 25-26 June 2013. In test cycle no. 1 staff from DHI, DESMI Ocean Guard and DNV GL surveyors prepared to initiate the shipboard testing with a ballast operation in Port Tangier, Morocco. However, due to inadequate ballast pump capacity and the vessel schedule the ballast operation was postponed and was conducted in Port of Lisbon instead.

During test cycles Nos. 2 and 3, ballast and de-ballast operations were conducted while the vessel was moored at the Alcântara Container Terminal in the port of Lisbon, Portugal, on 1-3 November 2013.

In test cycles No. 4 and 5, ballast operations were conducted while the vessel was moored at Porto Grande in Mindelo, Cape Verde on 27 January 2014 and de-ballast operations were conducted while the vessel was moored at Porto da Praia in Praia, Cape Verde, on 29 January 2014.

The holding time varied from approx. 5 to 47 hours for treated water and from 5 to 49 hours for control water. In all five shipboard test cycles, the RayClean BWMS was operated by a crew member (chief or second officer). Detailed data logging information for each test cycle is available in Appendix 2.

8 Sampling

8.1 Sample overview

All samples were collected by DHI staff in accordance with the description in the Test Plan. Test cycles Nos. 1, 4 and 5 consisted of sampling and analyses of:

- **Inlet water:** The physical/chemical and biological parameters in the inlet water were considered sufficiently stable during ballasting since the vessel was moored during ballast operations of both treated water and control water. Thus, only one set of samples and analyses were used to represent the control tank and the ballast tank.

- **Discharge control water:** Stored without treatment from the time of ballasting to discharge

- **Discharge treated water:** Treated and stored from the time of ballasting to discharge

Test cycles Nos. 2 and 3 were conducted with only one set of inlet and control discharge water samples. The operations for shipboard test cycles Nos. 2 and 3 were conducted in the following order:

1. Ballast operation shipboard test cycle No. 2 (1 November 2013)
2. Ballasting operation control water for shipboard test cycles Nos. 2 and 3 (1 November 2013)
3. Ballast operation shipboard test cycle No. 3 (1 November 2013)
4. Treated discharge shipboard test cycle No. 2 (3 November 2013)
5. Control discharge water (3 November 2013)
6. Treated discharge shipboard test cycle No. 3 (3 November 2013)

The approach with ballasting for shipboard test cycle No. 2 followed by ballasting of control water and ballasting for shipboard test cycle No. 3 immediately after each other was suggested by DESMI Ocean Guard. The intention was that shipboard test cycle No. 2 would represent a test cycle according to both IMO G8 guidelines /4/ and U.S Coast Guard requirements /2/ including control water (reference water) and shipboard test cycle No. 3 would represent a test cycle according to U.S. Coast Guard requirements. Since the vessel was moored during ballast operations the physical/chemical and biological parameters of the inlet water was considered stable during ballasting, and therefore only one set of samples and analyses was used to represent the control tank and the two ballast tanks. The testing approach for shipboard test cycles Nos. 2 and 3 was accepted by email from DNV GL received on 20 September 2013.

Table 8.1 Number of samples and sample volumes

Test cycle step	Number of samples	Type of sample	Sample volume per replicate
Inlet water	3 replicates	Organisms ≥50 µm	>1 m^3*
		Organisms 10-50 µm	2 L***
		Bacteria	≥0.5 L***
		DOC, POC, UV-T	≥0.5 L ***
		TSS	≥0.5 L***
Control discharge water	3 replicates	Organisms ≥50 µm	>1 m^3 *
		Organisms 10-50 µm	2 L***
		Bacteria	≥0.5 L ***
		DOC, POC	≥0.5 L ***
		TSS	≥0.5 L ***
Treated discharge water	3 replicates	Organisms ≥50 µm	>3 m^3 *
	3 replicates	Organisms 10-50 µm	10 L **
	3 × 3 replicates	Bacteria	≥0.5 L ***
	3 replicates	DOC, POC; UV-T	≥0.5 L ***
	3 replicates	TSS	≥0.5 L ***

* Collected by continuous flow during the entire period of intake or discharge with all three field replicates representing the entire operation period; for treated discharge, this time integrated continuous sampling of 3 replicates, each of a volume of >3 m^3, provides the same statistical basis for evaluation as the sampling 3 × 3 replicates of >1 m^3, which is recommended in the G8 guidelines

** Collected by continuous flow during the entire period of discharge with each field replicate representing approx. a third of the operation period; for treated discharge, this time integrated continuous sampling of 3 replicates, each of a volume of 10 L, provides the same statistical basis for evaluation as the sampling 3 × 3 replicates of 1 L, which is recommended in the G8 guidelines

*** Grab samples collected over the period of intake or discharge (e.g. start, middle and end)

DOC Dissolved organic carbon

POC Particulate organic carbon

TSS Total suspended solids

8.1.1 Samples for DOC, POC, UV-T and TSS analyses

Samples (3 replicates for the inlet water, 3 replicates for the control discharge water, and 3 replicates for the treated discharge water) of at least 0.5 L were collected in acid washed and heat-sterilized blue cap bottles for analyses of dissolved organic carbon (DOC), particulate organic carbon (POC) and UV transmittance (UV-T). For total suspended solids (TSS) analysis, samples with a volume of approx. 0.5 L were collected in polyethylene containers.

8.1.2 Samples for enumeration of organisms ≥50 µm

Three replicates were collected by parallel continuous sampling during the entire periods of intake and discharge. The samples were gently filtered through a net with a mesh size of 35 µm and a reservoir (cod-end) at the bottom of the net for collecting the zooplankton. Each replicate was concentrated in 1-L glass bottles. The total volume of the filtered sample was determined by a flow meter.

8.1.3 Samples for enumeration of organisms ≥10 μm and <50 μm

Grab samples were collected for the inlet water and for the control discharge water (3 replicates each) with each a volume of 2 L. Treated discharge water was collected by continuous flow during the entire period of discharge with each a volume of 10 L. The samples were collected in appropriate containers.

8.1.4 Samples for enumeration of organisms <10 μm

Grab samples (3 replicates for the inlet water, 3 replicates for the control discharge water and 3 × 3 replicates for the treated discharge water) with each a volume of at least 0.5 L were collected in appropriate sterile containers with sodium thiosulphate.

9 Data management, analyses and reporting

9.1 Data management

The recording and storage of data are described in the Quality Assurance Project Plan (QAPP; Appendix 1).

DHI collected the information relevant for the BE test cycles when DHI staff was present during the testing (volumes, operation times, flow rates, locations etc.). DHI was only present during the BE test cycles and, thus, DHI did not monitor or document the activities related to the installation and maintenance of RayClean on board the vessel (e.g. scheduled/ unscheduled maintenance, weather conditions and resultant effects, instrument calibration etc.). DESMI Ocean Guard's shipboard testing documentation describing ballast water operations during the shipboard testing period is enclosed in Appendix 3.

9.2 Analyses

The average temperatures of samples from collection during storage and transport to the DHI Environmental Laboratory ranged from 2.4 to 15°C for all the test cycles. Analyses performed on-board were performed within the shortest possible time period. Samples analysed in the DHI Environmental Laboratory were processed in the laboratory within 63 hours from sampling of discharge water. Detailed data on storage temperatures for different sample types are available in Appendix 4.

9.2.1 Analysis overview

Table 9.1 Overview of analyses and sample replicates

Samples and replicates	Organisms ≥ 50 µm	Organisms ≥10-<50 µm, microscopy	Organisms ≥10-<50 µm, algal re-growth	Organisms <10 µm	Temperature, salinity, turbidity	UV transmittance	DOC + POC	TSS
Inlet water								
Rep 1 (start)	3 continuous replicates	1	1	1	1	1	1	1
Rep 2 (mid)		2	2	2	2	2	2	2
Rep 3 (end)		3	3	3	3	3	3	3
Control discharge water								
Rep 1 (start)	3 continuous replicates	1	1	1	1	-	1	1
Rep 2 (mid)		2	2	2	2	-	2	2
Rep 3 (end)		3	3	3	3	-	3	3
Treated discharge water								
Rep 1-3 (start)	3 continuous replicates	3 continuous replicates		1-3	1	1	1	1
Rep 4-6 (mid)				4-6	4	4	4	4
Rep 7-9 (end)				7-9	7	7	7	7

DOC Dissolved organic carbon
POC Particulate organic carbon
TSS Total suspended solids

All analyses were carried out in accordance with the Test Plan and Amendments Nos. 1-3 (Appendix 1) and the relevant DHI standard operating procedures (DHI SOPs). The samples for all analyses were kept cool from the time of collection. During the storage and transport of samples to the laboratory, a temperature logger was placed with the samples to measure the variation of the temperature from sampling to final analysis. Samples were processed and analysed within the shortest possible time period.

9.2.2 Physical/chemical analyses

The physical/chemical analyses conducted during the shipboard test included:

- Temperature
- Salinity
- pH
- Oxygen saturation
- Turbidity
- UV transmittance (UV-T)
- Dissolved organic carbon (DOC)
- Particulate organic carbon (POC)
- Total suspended solids (TSS)

Work on location

Temperature, pH, oxygen saturation salinity and turbidity were measured by use of a portable instrument equipped with electrodes. Measurements were conducted at regular intervals throughout the inlet and discharge operations.

For determination of DOC and POC, the samples were treated as described in DHI SOP 30/1769. For determination of TSS, the samples were filtered through a glass fibre filter, which had already been dried and weighed at the DHI Environmental Laboratory as described in DHI SOP 30/1768. For determination of UV-T, a subsample with a volume of 100 mL for each replicate was transferred to glass bottles and kept in the dark until arrival at the DHI Environmental Laboratory.

Work in laboratory

Determination of DOC and POC was performed according to DHI SOP 30/1769. Determination of TSS was performed according to DHI SOP 30/1768. Determination of UV-T was performed according to DHI SOP 30/1770.

9.2.3 Organism size class ≥50 µm

Compliance with the pass criterion (Appendix 1, QAPP, Chapter 10) was verified by use of the direct count of organisms ≥50 µm in minimum dimension.

The concentrations of live organisms ≥50 µm in minimum dimension were determined by use of a stereo microscope and a counting chamber according to DHI SOP 30/1700. Live organisms were enumerated by use of standard movement and response to stimuli technique. The live organisms were characterized according to major taxonomic groups. The analyses were completed on location within six hours from the end of sampling.

9.2.4 Organism size class ≥10 µm and <50 µm

Compliance with the pass criterion (Appendix 1, QAPP, Chapter 10) was verified by use of the total of viable organisms determined by measuring algal re-growth in a most probable number (MPN) assay and enumeration of viable organisms ≥10 µm and <50 µm in minimum dimension that are not encompassed by the algal re-growth assay (i.e. chloromethylfluorescein diacetate (CMFDA)/fluorescein diacetate (FDA)-labelled organisms without chlorophyll).

Work on location

Samples preserved with Lugol's solution. Inlet and discharge water samples were preserved with Lugol's solution to enable determination of the concentrations of organisms in the size class ≥10 and <50 µm. The container with inlet or discharge water sample was shaken gently (upside down 5 times) and subsamples with an approx. volume of 100 mL were transferred to brown glass bottles. Two subsamples were collected for one replicate and one subsample was collected for the remaining two replicates. Lugol's solution was added to achieve a final concentration of 2% according to DHI SOP 30/1701.

Samples for CMFDA/FDA analysis. The container with the total sample was shaken gently (upside down 5 times). Subsamples of approx. 100 mL were transferred to brown glass bottles. Two subsamples were collected for one replicate and one subsample was collected for the remaining two replicates. These subsamples were stored in the dark and transported to the DHI Environmental Laboratory for further analysis.

Algal re-growth assay. In the inlet and discharge water samples, the concentrations of viable algae were analysed by measuring algal re-growth in a most probable number (MPN) assay. The container with the total sample was shaken gently (upside down 5 times). One subsample (approx. 15 mL) of undiluted water per replicate was kept in the dark as 'back-up samples'. Dilution series of the inlet water, control discharge water and treated discharge water were prepared by adding 1-mL aliquots of sample to test tubes with 5 mL of liquid medium as described in DHI SOP 30/1704. Ten (10) control test tubes containing only 5 mL of medium were prepared. The test tubes were kept in the dark until arrival at the DHI Environmental Laboratory.

In test cycle no. 1 the samples for the algal re-growth assay were transported to the DHI Environmental Laboratory, where the dilution series were prepared immediately upon arrival (25 hours after discharge and 34 hours after ballast operation). As described in section 7.1 the testing location was changed in the last minute from Port Tangier, Morocco to Port of Lisbon. After unpacking the DHI shipboard testing equipment on the vessel in Port Tangier it was suspected that a customs inspection had resulted damage to some of the equipment. For example, a manifold for sampling flow meters was damaged, even though the manifold was secured and well protected during shipment. Furthermore, many of the glass test tubes used for the dilution series and incubation for the algal re-growth analysis were broken after equipment shipment to the vessel in Port Tangier. As a result of this, there were not sufficient glass test tubes available to prepare the dilution series for all samples on location.

Work in laboratory

Samples preserved with Lugol's solution. These samples were analysed as follows:

- Inlet water. Assuming that practically all of the organisms in the natural water were alive, fulfilment of the validity criterion for the concentration of organisms ≥10 and <50 µm in the inlet water was confirmed by inverted microscopy enumeration according to DHI SOP 30/1701. The analyses comprised detailed examination of the algal chloroplasts (to confirm that the phytoplankton was alive at the time of sampling) and classification of the algae according to groups, taxa or species.

- Discharge water. Inverted microscopy was applied to quantify the predominant groups, taxa and species ≥10 and <50 µm in the treated discharge water with the purpose of adding to the documentation of the algal re-growth assay (see below).

CMFDA/FDA. Chloromethylflourescein diacetate (CMFDA) and fluorescein diacetate (FDA) were added to a subsample and, after incubation, the subsample was examined by use of a microscope under epifluorescence. Organisms labelled by either CMFDA or FDA were considered viable as described in DHI SOP 30/1701. These enumerations of CMFDA/FDA-stained organisms were applied to confirm that the validity criterion for the concentration of organisms ≥10 and <50 µm in the control discharge water was fulfilled. For treated discharge water, only CMFDA/FDA-labelled motile organisms without chlorophyll were included in the verification of treatment efficacy.

Algal re-growth assay. On arrival at the laboratory, the fluorescence of the test tubes was determined before incubation (t_0). The test tubes were incubated for 14 ± 1 days at ambient temperature of the sampling location as described in DHI SOP 30/1704. The concentrations of viable algae in the inlet water, control discharge water and treated discharge water were determined by measuring the fluorescence in the test tubes according to DHI SOP 30/1704.

The algal re-growth assay was documented by the growth of the naturally occurring algae under the conditions applied in the assay. Identification of groups, taxa or species in the local water capable of growth under the applied conditions was performed with inlet and control discharge water. In addition, the algal groups, taxa or species in the inlet and control discharge water were thoroughly analysed and compared with the list of algae capable of growing under the conditions in the algal re-growth assay, which has been obtained during land-based cycles in Hundested, Denmark and shipboard test cycles in several different locations (some of the groups, taxa or species may be the same across geographic regions). DHI is confident that the algal re-growth assay is conducted under conditions that support the growth of a versatile range of algal species. However, the limited number of test cycles (1 or 2) conducted during a shipboard test voyage implies that the list of algae identified in the inlet water and in the algal re-growth assay is less comprehensive compared with the list obtained from the large number of test cycles in Hundested.

9.2.5 Organism size class <10 µm (bacteria)

Compliance with the pass criterion (Appendix 1, QAPP, Chapter 9) was verified by use of a Bio-Rad MUG/MUD kit for *E. coli* and enterococci quantification. The presence of *Vibrio cholerae* was examined by identification of colony forming units (CFU) on solid media.

Work on location

E. coli and enterococci were determined according to DHI SOP 30/1708.

For detection of *Vibrio cholerae*, one sample per replicate was filtered through a 0.45-µm filter, after which the filter was kept moist in sterile polyethylene tubes.

Work in laboratory

The possible occurrence of *Vibrio cholerae* was analysed according to DHI SOP 30/1707.

10 Results

10.1 Physical-chemical parameters

For the RayClean BWMS, the physical-chemical conditions of inlet and discharge waters for all test cycles are summarized in Table 10.1 and Table 10.2. Onsite measurement data are provided in the data logging in Appendix 2. Detailed data on TSS, POC, DOC and mineral materials (MM), including temperatures during transport of samples, are provided in Appendix 4.

Table 10.1 Average concentrations (three replicates) of total suspended solids (TSS), particulate organic carbon (POC), dissolved organic carbon (DOC) and mineral materials (MM)

Test cycle	Water type	TSS (mg/L)	POC (mg/L)	DOC (mg/L)	MM (mg/L)*
No. 1	Inlet	81	1.2	0.90	80
	Control discharge	47	0.90	0.84	46
	Treated discharge	20	0.55	0.74	19
No. 2	Inlet	14	0.47	3.4	13
	Control discharge	7.2	0.26	1.7	6.9
	Treated discharge	6.9	0.24	3.5	6.7
No. 3	Inlet	14	0.47	3.4	13
	Control discharge	7.2	0.26	1.7	6.9
	Treated discharge	9.2	0.27	2.7	8.9
No. 4	Inlet	7.7	<0.1	2.4	7.6
	Control discharge	9.7	<0.1	1.0	9.6
	Treated discharge	6.4	0.11	1.2	6.3
No. 5	Inlet	6.2	<0.1	1.1	6.1
	Control discharge	7.1	<0.1	1.0	7.0
	Treated discharge	6.7	<0.1	1.2	6.6

* MM determined as the difference between TSS and POC as described in Section 5.4.6.1 of the ETV protocol /3/

Table 10.2 Average measurements of oxygen (O_2), salinity, temperature, pH, UV transmittance (UV-T) and turbidity

Test cycle	Water type	O_2 (mg/L)	Salinity (PSU)	Temp. (°C)	pH	UV-T (%)	Turbidity (NTU)
No. 1	Inlet control	6.5	34	17	7.9	70 (96)	28
	Inlet BWMS	6.4	34	17	7.9		13
	Control discharge	6.5	34	17	7.9	-	18
	Treated discharge	6.5	34	18	7.9	88 (97)	10
No. 2	Inlet control	5.7	29	19	7.4	80 (91)	8.7*
	Inlet BWMS	6.1	31	19	7.4	53 (93)	56*
	Control discharge	6.3	30	19	7.4	-	20
	Treated discharge	5.6	31	19	7.4	86 (94)	5.0
No. 3	Inlet control	5.7	29	19	7.4	80 (91)	8.7*
	Inlet BWMS	6.4	30	19	7.4	71 (91)	38*
	Control discharge	6.3	30	19	7.4	-	20
	Treated discharge	5.7	31	19	7.4	84 (93)	7.3
No. 4	Inlet control	6.2	37	22	8.1	96 (97)	5.3
	Inlet BWMS	5.9	37	22	8.2		4.9
	Control discharge	6.5	37	23	8.1	-	3.3
	Treated discharge	6.5	37	23	8.1	97 (98)	4.0
No. 5	Inlet control	6.1	37	22	8.2	92 (96)	4.3
	Inlet BWMS	6.1	37	22	8.2		4.0
	Control discharge	6.8	37	23	8.1	-	3.0
	Treated discharge	6.5	37	23	8.1	93 (98)	3.3

PSU Practical salinity units
NTU Nephelometric turbidity units
UV-T UV transmittance (figures in parentheses represent UV-T measured in 0.2-µm filtered samples)
* The turbidity in the inlet water varied during the ballast operation as a result of passing vessels stirring up sediment

10.2 Biological parameters

The densities of live organisms in the inlet and control discharge water in test cycles Nos. 1-5 were in accordance with the IMO G8 guidelines and the ETV protocol and, thus, these test cycles were considered valid. Detailed data from the biological efficacy analyses are available in Appendix 4.

The densities of viable organisms in the treated discharge water were below the ballast water discharge standard /1/, /2/ for all test cycles performed.

10.2.1 Organism size class ≥50 µm

The densities of viable organisms from the ≥50 µm size class in the inlet and control discharge water were in accordance with the IMO G8 guidelines and the ETV protocol in all test cycles. The average densities varied from approx. 5,500 to 92,000 organisms/m^3 in the inlet water and from approx.1,000 to 72,000 organisms/m^3 in the control discharge water.

In the treated discharge water, the average concentrations of viable organisms in the ≥50 µm size range are summarized in Table 10.3. For treated discharge samples, the total volume of each of the three field replicates was analysed within six hours from completion of the sampling. The average concentrations of viable organisms in ≥50 µm in the treated discharge water were 5.2; 9.4; 1.9; 0; and 0 organisms/m^3 for test cycles Nos. 1-5 respectively, which were all below the pass criterion defined in the ballast water discharge standard.

Table 10.3 Total sample volumes and average numbers (three replicates) of viable organisms in the size class ≥50 µm. Specific data and individual sample volumes are provided in Appendix 4.

Test cycle	Water type	Total sample volume (m^3)	Organisms/m^3
No. 1	Inlet	4.7	91,975
	Control discharge	3.6	71,696
	Treated discharge	9.2	5.2
No. 2	Inlet	3.6	6,201
	Control discharge	3.6	4,489
	Treated discharge	9.7	9.4
No. 3	Inlet	3.6	6,201
	Control discharge	3.6	4,489
	Treated discharge	9.5	1.9
No. 4	Inlet	4.5	5,533
	Control discharge	3.2	1,837
	Treated discharge	9.2	0
No. 5	Inlet	5.1	6,814
	Control discharge	3.1	1,044
	Treated discharge	9.1	0
Require-ments	Inlet*	≥3	≥100
	Control discharge*	≥3	≥10
	Treated discharge	≥9	<10

* Minimum criteria for live organism densities according to the IMO G8 guidelines /4/ and the ETV protocol /3/

10.2.2 Organism size class ≥10 and <50 μm

As stated in the Test Plan (Appendix 1), fulfilment of the validity criterion for the concentration of organisms ≥10 and <50 μm in the inlet water was based on inverted microscopy enumeration according to DHI SOP 30/1701.

The densities of viable organisms from the ≥10 and <50 μm size class in the inlet water were in accordance with the requirement in the IMO G8 guidelines and the ETV protocol in all test cycles, except for test cycles Nos. 2 and 3, in which the average number of viable organisms in the ≥10 and <50 μm size class was determined to be 99 organisms/mL (Table 10.4) with a standard deviation of ±1 (instead of ≥100 organisms/mL). This difference is considered negligible and without influence on the results. Furthermore, in the control discharge water from test cycles No. 2 and 3, the average density of viable organisms in the ≥10 and <50 μm size class was determined to be 106 organisms/mL. The average density of 99 organisms/mL in the inlet water from test cycles Nos. 2 and 3 was accepted by DNV GL in an email dated 19 November 2013 as meeting the requirement for a valid test cycle. In test cycles Nos. 1, 4 and 5 the average densities of viable organisms ≥10 and <50 μm in the inlet water varied from 131 to 375 organisms/mL when determined by inverted microscopy (Table 10.4). Densities of viable organisms from the ≥10 and <50 μm size class in the control discharge water were in accordance with the IMO G8 guidelines and the ETV protocol in all test cycles. In the control discharge water in test cycles Nos. 1, 4 and 5, the average densities of viable organisms ranged from 16 to 149 organisms/mL when determined by microscopic counting of CMFDA/FDA-stained samples.

The algal taxa and species capable of growing under the conditions applied in the algal re-growth assay represented 67-82% of the identified algae in the inlet water (Appendix 4).

Table 10.4 summarizes the concentrations of viable organisms ≥10 and <50 μm based on two different evaluation methodologies. The quantitative evaluation of the performance at discharge after the second treatment was based on (i) microscopic counting after staining with CMFDA and FDA and (ii) most probable number of proliferating algae and addition of CMFDA/FDA-stained motile organisms without chlorophyll.

Microscopic counting after staining with CMFDA and FDA

The numbers of CMFDA/FDA-stained organisms ≥10 and <50 μm at discharge were 5.0; 4.5; 2.3; 0.83; and 0.42 organisms/mL in test cycles Nos. 1 to 5, respectively (treated discharge samples in Table 10.4).

Most probable number of proliferating algae and addition of CMFDA/FDA-stained motile organisms without chlorophyll

The total numbers of the MPN obtained in the algal re-growth assay and the CMFDA/FDA-stained motile organisms without chlorophyll at discharge were 0.44; 0.35; 0.28; 0.19; and <0.18 organisms/mL in test cycles Nos. 1 to 5, respectively (treated discharge samples in Table 10.4).

Table 10.4 Average numbers (three replicates) of viable organisms in the size class ≥10 µm and <50 µm. Specific data including storage temperatures during transport are provided in Appendix 4.

Test cycle	Water type	Microscopy (organisms/mL)		Algal re-growth (org/mL)	Algal re-growth (%)**	Algal re-growth + CMFDA/FDA stained-motile organisms without chlorophyll (organisms/mL)
		Total number	Motile without chlorophyll*			
No. 1	Inlet	375	-	>160	82	>160
	Control discharge	149	3.0	>160		>163
	Treated discharge	5.0	0	0.44		0.44
No. 2	Inlet	99	-	>160	82	>160
	Control discharge	106	14	>160		>174
	Treated discharge	4.5	0.17	0.19		0.35
No. 3	Inlet	99	-	>160	82	>160
	Control discharge	106	14	>160		>174
	Treated discharge	2.3	0	0.28		0.28
No. 4	Inlet	131	-	137	67	137
	Control discharge	16	1.3	137		139
	Treated discharge	0.83	0	0.19		0.19
No. 5	Inlet	137	-	137	75	137
	Control discharge	20	0	>160		>160
	Treated discharge	0.42	0	<0.18		<0.18
Require-ments	Inlet***	≥100	-	-	-	-
	Control discharge***	≥10	-	-	-	-
	Treated discharge	<10	<10	<10	-	<10

* The concentrations of motile organisms without chlorophyll are included in the total number of organisms

** Algal taxa and species confirmed able to grow under the conditions in the re-growth assay (per cent of the taxa and species identified in the inlet water of the respective test cycles; data from Appendix 4, Table A.4.4.3)

*** Minimum criteria for live organism densities according to the IMO G8 guidelines /4/ and the ETV protocol /3/

10.2.3 Bacteria

For shipboard testing, there are no requirements in relation to the density of bacteria in the inlet water or the control discharge water. The average concentrations of *E. coli* ranged from 14-1,520 CFU/100 mL in the inlet water and from <10 - 690 CFU/100 mL in the control discharge water. For enterococci, average concentrations ranged from <10 - 273 CFU/100 mL in the inlet water and <10 - 113 CFU/100 mL in the control discharge water. *Vibrio cholerae* was not identified in all inlet and control discharge water samples.

Table 10.5 Average bacterial concentrations. Specific data are provided in Appendix 4.

Test cycle	Water type	*E. coli* (CFU/100 mL)	Enterococci (CFU/100 mL)	*Vibrio cholerae* (CFU/100 mL)
No. 1	Inlet	417	47	Absent
	Control discharge	193	25	Absent
	Treated discharge	<10	<10	Absent
No. 2	Inlet	1,520	273	Absent
	Control discharge	690	113	Absent
	Treated discharge	37	<10	Absent
No. 3	Inlet	1,520	273	Absent
	Control discharge	690	113	Absent
	Treated discharge	<10	<10	Absent
No. 4	Inlet	24	<10	Absent
	Control discharge	113	<10	Absent
	Treated discharge	107	<10	Absent
No. 5	Inlet	14	<10	Absent
	Control discharge	<10	<10	Absent
	Treated discharge	<10	<10	Absent
Require-ments	Treated discharge	<250	<100	<1

CFU Colony-forming units

In the treated water, the average concentrations of *E. coli* and enterococci were below the ballast water discharge standard /1/, /2/ for all test cycles performed. *Vibrio cholerae* was not identified in any of the test cycles.

In test cycle No. 4, the average concentrations of *E. coli* in the discharge water (both treated and control) were approx. 5 times higher than the concentrations of *E. coli* in the inlet water suggesting that *E. coli* was present in the ballast tanks or in the piping system on the vessel.

In test cycles Nos. 4 and 5, unidentified bacteria were seen on the majority of the agar plates (inlet, control discharge and treated water) for detection of *Vibrio cholerae*. After inspection of the bacterial colonies on the agar plates, seven colonies with morphological characteristics resembling *Vibrio cholerae* were analysed at Statens Serum Institut (SSI) for species identification. The selected colonies were obtained from inlet, control discharge and treated discharge water in test cycles Nos. 4 and 5. None of the seven colonies were *Vibrio cholerae* (see Appendix 5).

11 Quality assurance and quality control

The biological efficacy performance evaluation in shipboard test of the RayClean BWMS was conducted in accordance with ISO 9001 by using the DHI Business Management System certified by DNV GL. The DHI Environmental Laboratory is accredited by DANAK, the Danish Accreditation and Metrology Fund, to perform ecotoxicological studies and analyses aiming at the performance evaluation of BWMS in accordance with ISO 17025. The performance evaluation also complied with the conditions included in the Quality Management Plan (QMP), QAPP, the Test Plan and the DHI SOPs (see Appendix 6). Three amendments describing planned changes to the Test Plan were made during the performance evaluation period. The QMP, the Test Plan (including QAPP) and the Amendments Nos. 1-3 are included in Appendix 1.

The acting classification society for the shipboard performance evaluation of RayClean was DNV GL. The Test Plan (including the QAPP) was reviewed by DNV GL. The DNV GL review report is included in Amendment No. 1 (Appendix 1).

DNV GL staff also conducted an onsite inspection during the ballast operations of test cycle No. 1. The inspection included the BE testing activities on board the vessel Thurø Mærsk. The comments from the DNV GL review of the Test Plan and the onboard inspections were addressed in the final version of the Test Plan, Amendments Nos. 1-3 and in this final report. The DNV GL survey report is included in Appendix 1.

12 References

/1/ IMO. International Convention for the Control and Management of Ships' Ballast Water and Sediments. London. International Maritime Organization, 2004.

/2/ U.S. Coast Guard. Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters. Federal Register, Vol. 77, No. 57, 23 March 2012.

/3/ U.S. Environmental Protection Agency, Environmental Technology Verification Program. Generic Protocol for the Verification of Ballast Water Treatment Technology. EPA/600/R-10/146, September 2010.

/4/ MEPC. Guidelines for Approval of Ballast Water Management Systems (G8). Resolution MEPC.174(58). Adopted 10 October 2008.

APPENDIX 1

QMP and Test Plan (including QAPP) with Amendment Nos. 1-3 and DNV GL survey report

Quality Management Plan

Biological Efficacy Performance Evaluation of Ballast Water Management Systems

DHI Denmark

Version 3.2

October 2012

Quality Management Plan

Biological Efficacy Performance Evaluation of Ballast Water Management Systems

DHI Denmark
Version 3.2

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1 DEFINITIONS

Terms/Abbreviations	Definitions
Active substance	Active substance means a chemical or an organism, including a virus or a fungus, that has a general or specific action on or against nonindigenous species
Ballast water management system (BWMS)	A system which processes ballast water to kill, render harmless or remove organisms. The BWMS includes all ballast water treatment equipment and all associated control and monitoring equipment
Classification society	Independent classification society that conducts formal verification of the procedures applied in performance evaluation of BWMS
DHI Standard operating procedure (DHI SOP)	Document describing the procedures or characteristics for analyses, operations or tests Note: In-house methods may be used in the absence of a recognized standard, if they are commonly accepted for testing of BWMS or scientifically documented
Guidelines and standards	Guidelines means the IMO Guidelines for Approval of Ballast Water Management Systems (G8) (Reference /2/) and Procedure for Approval of Ballast Water Management Systems that Make Use of Active Substances (G9) (Reference /3/) or the U.S. Coast Guard Standards (Reference /4/) and the ETV protocol (Reference /5/)
IMO convention	The International Convention for the Control and Management of Ship's Ballast Water and Sediments adopted by the International Maritime Organization (IMO) (Reference /1/)
Independent Laboratory	Independent organisation that meets the requirements in 46 CFR 159.010-3
International Maritime Organization (IMO)	United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships
Manufacturer (or client)	The manufacturer of a BWMS or related technology, or a party associated with such technologies, requesting a technology performance evaluation (sometimes referred to as vendor); the manufacturer is the party entering a Contract with DHI on the performance evaluation of the BWMS
Quality Assurance Project Plan (QAPP)	Project-specific technical document reflecting the implementation of quality assurance and quality control activities, the testing organisation, the testing conditions and analyses, and other conditions affecting the actual design and implementation of the required tests and evaluations Note: The DHI Business Management System applies Quality Assurance Plan as the equivalent term for the QAPP
Quality Management Plan (QMP)	Generic standard operating procedure within the DHI Business Management System describing the project management and quality control management structure
Services	When used in this QMP the term 'services' has the meaning described in Chapter 3
Test Plan	Project-specific technical document reflecting the specifics of the BWMS to be tested, the appointed classification society or Independent Laboratory, the selection of analytical procedures described in the QAPP, and other specific conditions related to the actual BWMS performance evaluation

U.S. Coast Guard	The U.S. Coast Guard is an organisation with the United States Department of Homeland Security. The Coast Guard is amending its regulations on ballast water management and engineering equipment by establishing a standard for the allowable concentration of living organisms in ships' ballast water discharged in waters of the United States and by establishing an approval process for BWMS

2 INTRODUCTION

The International Maritime Organization (IMO) has adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments /1/ to reduce the risk of spreading of harmful aquatic organisms and pathogens released with ballast water.

The IMO convention requires that all ships comply with specified water quality requirements (D2) before ballast water is released into the environment.

The performance evaluation of ballast water management systems (BWMS) aims at documenting compliance with the requirements stated in international guidelines, e.g.:

- Guidelines for Approval of Ballast Water Management Systems (G8) /2/
- Procedure for Approval of Ballast Water Management Systems that Make Use of Active Substances (G9) /3/.

DHI provides services in relation to performance evaluation of maritime technologies and particularly BWMS. DHI's land-based test facility in Denmark, the DHI Maritime Technology Evaluation Facility, is located in Hundested. DHI has also a land-based test facility for performance evaluation of BWMS in Singapore.

The DHI Ballast Water Centre is a coordinating structure between DHI Denmark and DHI Singapore. DHI Ballast Water Centre is organized with a Ballast Water Facility Board including two members from the management in DHI Denmark and two members from the management in DHI Singapore. The object of the Board is to coordinate the development and marketing of services related to the performance evaluation of BWMS within the DHI Group.

The Quality Management Plan (QMP) is a generic standard operating procedure within the DHI Business Management System.

3 SERVICES

The QMP covers the services provided by DHI Denmark at the facilities below:

DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark

and

DHI Maritime Technology Evaluation Facility
Færgevejen 18
DK-3390 Hundested
Denmark

The services include:

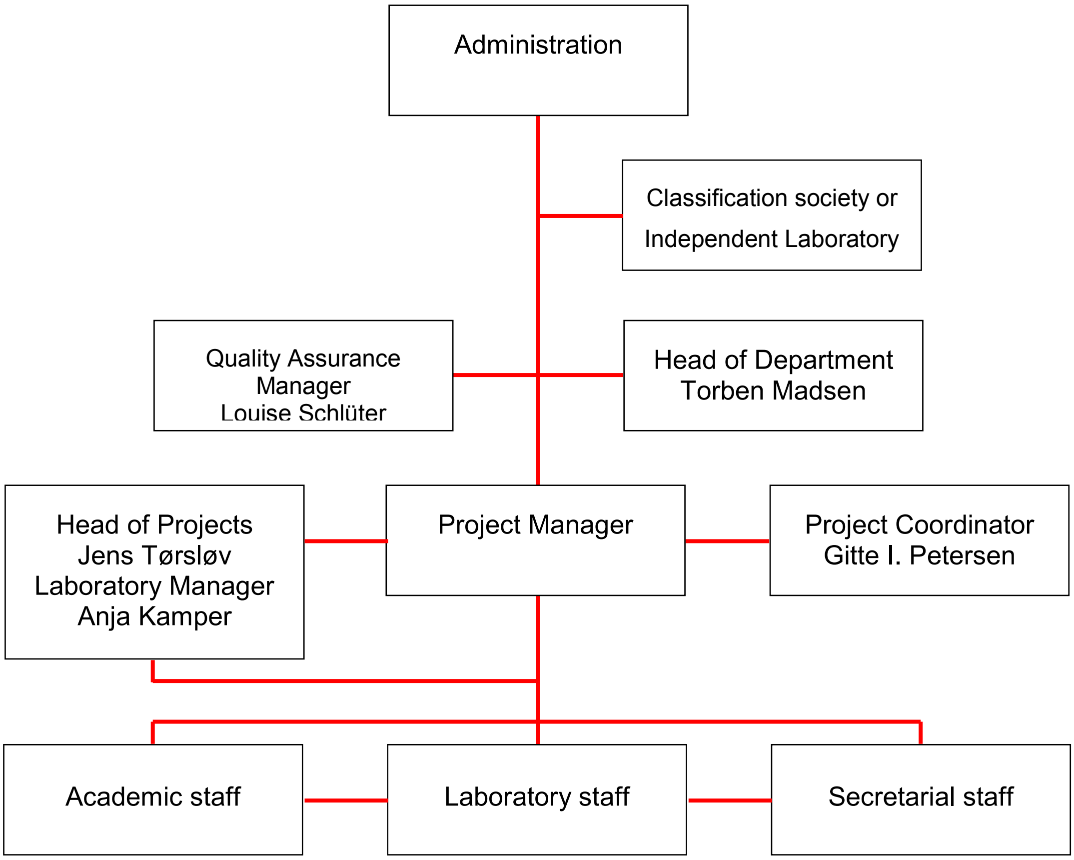
- Laboratory tests of BWMS, or ballast water treatment equipment, normally conducted at the DHI environmental laboratory in Hørsholm, Denmark, and aiming at e.g. proof-of-concept or technology optimisation prior to initiation of formal performance evaluation meeting the guidelines
- Pilot-tests of BWMS, or ballast water treatment equipment, conducted at the test facility or other facilities than a laboratory, and aiming at e.g. proof-of-concept or technology optimisation prior to initiation of formal performance evaluation meeting the guidelines
- Land-based tests of BWMS, or ballast water treatment equipment, conducted at the test facility and aiming at formal performance evaluation meeting the guidelines (e.g. type approval)
- Shipboard tests of BWMS, or ballast water treatment equipment, conducted on board vessels on which the technology is installed and aiming at formal performance evaluation meeting the guidelines (e.g. type approval).

The above activities are collectively referred to as the “services” whereas individual activities are referred to as “projects”.

The aim of the services is to provide independent, third party documentation for the performance of maritime technologies. High quality of the services is ensured through extensive quality management and use of skilled staff.

4 ORGANISATION

DHI’s project organisation is illustrated below.



4.1 Quality Assurance Manager

Senior biologist Louise Schlüter (Ph.D.) is assigned by DHI's Quality Assurance (QA) Unit as internal auditor. This includes the following tasks:

- Drafting of a plan for quality assurance
- Monitoring of compliance with the Quality Management Plan (QMP), the Quality Assurance Project Plan (QAPP), the Test Plan and the DHI standard operating procedures (DHI SOPs) by audit including the Project Manager and the laboratory staff
- Monitoring compliance with the appropriate guidelines or standards by audit including the Project Manager
- Verification of the presence of applicable staff training records
- Drafting of audit reports and verification that audit responses are appropriate and that corrective action has been implemented effectively
- Verification that the final product complies with DHIs standards for QA and, particularly, the QMP, the QAPP, the Test Plan and the guidelines and standards

4.2 Head of Department

Head of Department Torben Madsen (Ph.D.) is quality supervisor for all projects (described in the section on Services) and has the overall responsibility for the services related to performance evaluation of BWMS provided by DHI Denmark. This includes the following tasks:

- Member of the Ballast Water Test Facility Board for DHI Ballast Water Centre, a coordinating structure between DHI Denmark and DHI Singapore
- Overall responsibility for the test facility and the environmental laboratory including safe conditions of work and decisions on investments and maintenance expenses
- Overall responsibility for the liaison and contractual relations between DHI and Lloyds Register EMEA (certification of test facility), between DHI and the Danish Accreditation and Metrology Fund, DANAK (accreditation of analyses), and between DHI and the Independent Laboratory (subcontractor agreement)
- Negotiation of contracts with manufacturers (or clients)
- Appointment of Project Managers and staff responsible for quality control (QC) of individual data (data-level QC) and maintenance of staff experience records (allocation of Project Managers for specific projects is the responsibility of the Head of Projects)
- Maintenance of the QAPP and the QMP with updated versions as appropriate
- Quality control of the QAPP, Test Plan, DHI SOPs and all project proposals, deliverables and reports
- Documentation in relation to
    - Staff training and experience
    - Facilities and their maintenance
    - Records of complaints

4.3 Project Coordinator

Business Area Manager Gitte I. Petersen (Ph.D.) is responsible for the coordination, timely execution and the overall scientific quality of the services. This includes the following tasks:

- Business development and marketing
- Contact and dialogue with Lloyds Register EMEA prior to inspections and for management of the actions and documentation, in collaboration with the Laboratory Manager, as required to comply with the Certificate of Compliance issued by Lloyds Register EMEA
- Contact and dialogue with the Independent Laboratory prior to inspections and for management of the actions and documentation, in collaboration with the Laboratory Manager, as required to comply with the agreement between DHI and the Independent Laboratory
- Coordination of the services to ensure optimal logistics at the test facility, including decisions related to the practical installation of manufacturers and their technology and timing of tests
- Maintenance of the test facility including routine technical maintenance and dialogue with the Head of Department in relation to investments and maintenance expenses
- Instruction of staff with responsibility for specific tasks such as, e.g., test facility technical operations and production of test water

- Principal scientific expert with responsibility for the overall scientific quality of the services including compliance with official guidelines, standards, protocols, and requirements from classification societies and Independent Laboratories; this implies input to the QAPP and the Test Plan, revisions and implementation of DHI SOPs, and contributions to data interpretation and reporting in collaboration with the Project Manager
- Participation in discussions with the classification society or Independent Laboratory on important matters, particularly draft and final reports, together with the Project Manager

4.4 Head of Projects and Laboratory Manager

Head of Projects Jens Tørsløv (Ph.D.) has the overall responsibility for allocation of staff, planning and project execution in coordination with the Project Coordinator or the Project Manager as appropriate.

Laboratory Manager Anja Kamper (M.Sc.) allocates laboratory technicians for a specific project as part of the laboratory capacity planning by allocation of responsibility from the Head of Projects. Furthermore, the Laboratory Manager appoints one or more test co-ordinators among the laboratory technicians or the academic staff for on-site coordination of land-based test cycles.

The Laboratory Manager is responsible for the contact and dialogue with DANAK prior to inspections and for management of the actions and documentation as required to comply with the ISO 17025 accreditation.

4.5 Project Manager

The **Project Manager** is responsible for the management and efficient performance of the project in accordance with the Contract between the manufacturer and DHI, the QMP, the QAPP and the Test Plan.

The Project Manager's tasks include:

- Organisation and management of the project
- Meetings and other communication with the manufacturer to ensure that all necessary information is available in due time
- Preparation of the draft and final Test Plan with detailed description of the project, including time schedule of activities and deliverables; the QAPP and the Test Plan shall be made available to all staff participating in the project
- Facilitation of the process for comments and responses to the QAPP and the draft Test Plan in dialogue with the manufacturer and the classification society or the Independent Laboratory
- Preparation of amendments and deviations to the Test Plan
- Communication of the project time schedule to the classification society or the Independent Laboratory to enable external audit
- Participation in discussions with the classification society or the Independent Laboratory on important matters, particularly draft and final reports, together with the Project Coordinator

- Coordination and dialogue with the Laboratory Manager in relation to the practical organisation of work involving laboratory technicians; the Project Manager shall in due time inform the Laboratory Manager on the types of tests and the required capacity to enable laboratory capacity planning
- Contracts with subcontractors (e.g. chemical analytical laboratory) as appropriate for meeting the project deliverables
- Approval of initiation of the test cycles and interruption of test cycles, e.g. in case of irregularity
- Preparation of reports

4.6 Academic staff, laboratory staff and secretaries

The tasks of the academic staff, the laboratory staff and the secretaries include:

- Maintenance of materials and equipment
- Test facility technical operations
- Test coordinator function, i.e. coordination and keeping timely records of the activities at the test facility during land-based tests
- Production of test water and monitoring of test water quality
- Sampling at the test facility
- Analysis and data processing, including data-level QC
- Contributions to test reports
- Archiving of documents and raw data
- Contributions to QAPPs, Test Plans and DHI SOPs

4.7 Manufacturer

The tasks of the representative of the manufacturer include:

- Signing a Contract with DHI for the BWMS performance evaluation project
- Project management of the manufacturers activities in the project, including the liaison with DHI and decisions in relation to the testing
- Review and comments to the draft Test Plan and approval of the final Test Plan
- Collaboration with DHI to establish all necessary arrangements prior to initiation of the test
- Review and comments to draft test reports
- Analysis and data processing, including data-level QC
- Dismantling and removal of the BWMS from the test facility after ended testing

5 TRAINING

The Quality Assurance Manager verifies the presence of appropriate training records for staff participating in performance evaluation of BWMS (Section 4.1). The Head of Department is responsible for the appointment of specific staff and documentation of training and experience records for the staff conducting the operations, sampling, analyses, data-interpretation and reporting in relation to performance evaluation of BWMS. Staff without experience in the tasks required for the performance evaluation of BWMS receives appropriate training by a peer with documented experience in the relevant tasks before participation in the testing of BWMS. Approval of staff after completed training is the responsibility of the Head of Department who appoints Project Managers and staff responsible for QC (Section 4.2), and the Laboratory Manager who appoints laboratory technicians and test coordinators for specific tasks (see Section 4.4). Laboratory technicians (and academic staff conducting analyses) must demonstrate the required skills at least once per year by use of the data quality indicators in the relevant DHI SOPs.

For performance evaluation projects, where the equipment shall be operated by DHI, the manufacturer is required to provide training of the DHI staff prior to the start of testing. DHI documents the training with a statement, signed by the manufacturer, describing the names of DHI staff who have received the training and, if appropriate, confirms that this staff have achieved the skills to train other DHI staff members.

6 PERFORMANCE OF PROJECT

6.1 Contract

A Contract between the manufacturer and DHI is negotiated and signed according to the DHI manual for project management.

6.2 Quality Assurance Project Plan

The QAPP corresponds to the Quality Assurance Plan in the DHI Business Management System. The QAPP is a project-specific technical document reflecting the implementation of quality assurance and quality control activities, the testing organisation, the testing conditions and analyses, and other conditions affecting the actual design and implementation of the required tests and evaluations.

The performance evaluation of the BWMS is described by the QAPP together with the specific details provided in the Test Plan. A QAPP (and a Test Plan) are required for performance evaluation of BWMS in land-based or shipboard tests conducted according to international guidelines and standards, but these documents may be applied for any study where a formal study protocol is needed.

6.3 Test Plan

The Test Plan is a project specific technical document reflecting the specifics of the BWMS to be tested, the appointed classification society or Independent Laboratory, the selection of analytical procedures described in the QAPP, and other specific conditions related to the actual BWMS performance evaluation

The Test Plan is

- Prepared by the project manager
- Signed by the Project Manager and the Head of Department (quality supervisor)

- Forwarded to the classification society or Independent Laboratory for review and comments
- Forwarded to the manufacturer for review, acceptance and signature.

The Test Plan typically includes the following titles:

1. Project description and treatment performance objectives
2. Project organisation and personnel responsibilities
3. Description of testing laboratory
4. Description of ballast water management system
5. Experimental design
6. Sampling and analysis plan
7. Data management, analyses and reporting
8. Amendments and deviations
9. Land-based (or shipboard) testing requirements
11. Time schedule
12. References

Amendments and deviations to the Test Plan are approved and signed by the Project Manager. Amendments describe planned changes whereas deviations describe unplanned changes to the Test Plan.

6.4 Services

The project will be conducted as described in the QAPP and the Test Plan with subsequent amendments and deviations or, alternatively, as described in the Contract between the manufacturer and DHI.

6.4.1 Laboratory tests

Laboratory tests can be initiated when the technology is ready for testing and DHI's deliverables are defined. Initiation of testing is decided by the Project Manager in agreement with the manufacturer.

6.4.2 Pilot tests

Pilot tests can be initiated when the technology is installed and ready for operation. Initiation of testing is decided by the Project Manager in agreement with the manufacturer.

6.4.3 Land-based tests

Land-based tests can be initiated when the technology, typically a fully integrated BWMS, is installed and ready for operation. Initiation of testing is decided by the Project Manager in agreement with the manufacturer.

The Project Manager decides when a test cycle in the land-based test is completed and valid, when appropriate by reference to the IMO G8 or G9 guidelines /2; 3/, US standards /4; 5/ or other standards. If required, the Project Manager can decide to interrupt a test cycle due to technical malfunctioning of the test facility or the technology, insufficient state of biological or physical parameters or for other reasons related to the quality of the test water.

6.4.4 Shipboard tests

Shipboard testing can be initiated when the technology, typically a fully integrated BWMS, is installed on the vessel and ready for operation. Initiation of testing is decided by the Project Manager in agreement with the manufacturer.

The Project Manager decides when a test cycle in the shipboard test is completed and valid by reference to the IMO G8 guidelines /2/ or, if appropriate, to US standards /4; 5/. If required, the Project Manager can decide to interrupt a test cycle due to technical malfunctioning of the technology, insufficient state of biological or physical parameters or for other reasons related to the water quality.

6.5 Reports

Reports are prepared with the details, format and language described in the Contract between the manufacturer and DHI.

6.5.1 Performance evaluation of BWMS aiming at type approval

For land-based or shipboard tests of BWMS conducted as part of the type approval process (e.g. under the IMO convention or U.S. Coast Guard Standards), the report shall include all relevant technical and analytical data and will typically contain the following items:

- Name of the manufacturer
- Executive summary
- Introduction (including a description of the test facility)
- Experimental design (including the dates for initiation and completion of tests or test cycles and procedures stated in the QAPP and the Test Plan)
- Results (presented in summarizing tables and as raw data)
- Description of the BWMS (provided by the manufacturer)
- The signed QMP, QAPP and Test Plan with all amendments and deviations

The report shall be signed by the Project Manager and the Head of Projects.

The final report will be prepared in English and forwarded to the manufacturer.

7 QUALITY MANAGEMENT PROCESSES

7.1 Quality assurance

The services are conducted in accordance with the principles of ISO 9001 by using the DHI Business Management System and the procedures in the QMP. The DHI Business Management System is found compliant with ISO 9001 as part of the ISO 17025 accreditation of the DHI Environmental Laboratory.

The DHI Quality Manager is responsible for assigning a trained internal auditor from DHI's Quality Assurance Unit to each project in accordance with the procedures for internal audit in the DHI Business Management System (section on Quality). The internal auditor shall not be involved in solving the specific project or in any project deliverables.

The DHI Business Management System (section on Quality; Internal Audit) describes procedures for audit and evaluation and the process of periodic internal auditing of projects and activities including audit responsibilities and planning, auditor training and competences and audit reporting.

The DHI Business Management System (section on Quality; Correction and Prevention) describes procedures for corrective actions, i.e. how deviations identified during operation and auditing are corrected and how future occurrence of the same deviations is prevented (preventive actions).

7.2 Document and record control

The DHI Business Management System (section on Quality; Documents and Records) includes a procedure describing the process of drafting, revising and approving documentation.

The DHI Business Management System (section on Quality/ Laboratory Analysis/ Testing and Products with reference to DHI SOPs 30/921 and 30/937) describes how records of the test are stored, transferred, maintained and controlled in order to ensure data integrity for a period defined in the QAPP, but not shorter than five (5) years after issue of the final report.

7.3 Subcontractor management

The DHI Business Management System (Section on Consulting / Administration / Contracting) describes how it is ensured that subcontractors follow quality requirements.

In addition, analytical laboratories providing analyses of any kind should:

- Maintain an ISO 17025 accreditation with the quality management system required herein.
- Apply accredited analytical methods when available.
- Apply other methods according to either international standard methods or in-house methods that are in all cases validated as required for accredited methods.

DHI SOP 30/700 furthermore describes how it is ensured that purchased items such as chemicals and glassware are controlled, accepted and calibrated.

7.4 Staff competence management

The DHI Business Management System (section on Human Resources; Development) describes how it is ensured that the projects are conducted by staff with adequate competences and knowledge. This is done by maintaining a list of functions in the test process with competence requirements and responsibilities. The list is supported by reference to staff files in the DHI CV database.

7.5 Facility management

The DHI Business Management System (Laboratory Analysis and Testing with reference to DHI SOP 30/945) describes how it is ensured that facilities and equipment are available and fit for the purposes.

7.6 Management review

The DHI Business Management System (section on Quality; Management Review) describes how the DHI management is ensuring that DHI is working according to this QMP through mechanisms such as e.g. an annual management review process.

The Quality Manager is responsible for maintenance and development of the quality system and for the internal auditing of all aspects of the system – with daily reference to the Director, Group R&D and Quality Management. The DHI Business Management System contains rules for reviews of the quality system.

7.7 Complaint management

The DHI Business Management System (section on Customer Satisfaction) describes how complaints are recorded, resolved and reported. If not resolved, complaints are handled according to the Contract between the manufacturer and DHI.

8 REFERENCES

/1/ IMO. International Convention for the Control and Management of Ships' Ballast Water and Sediments. London. International Maritime Organization, 2004.

/2/ MEPC. Guidelines for Approval of Ballast Water Management Systems (G8). Resolution MEPC.174(58). Adopted 10th October 2008.

/3/ MEPC. Procedure for Approval of Ballast Water Management Systems that Make Use of Active Substances (G9). Resolution MEPC.126(53) Adopted 22nd July 2005.

/4/ U.S. Coast Guard. Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters. Federal Register, Vol. 77, No. 57, March 23, 2012.

/5/ U.S. Environmental Protection Agency, Environmental Technology Verification Program. Generic Protocol for the Verification of Ballast Water Treatment Technology. EPA/600/R-10/146, September 2010.

A P P E N D I X   A

BMWS testing-specific Standard Operating Procedures (DHI SOPs)

SUBJECT/SUBSUBJECT	DHI SOP NO.
ANALYTICAL METHOD DETERMINATION OF VIABLE ORGANISMS ≥50 µm	30/1700
ANALYTICAL METHOD DETERMINATION OF VIABLE ORGANISMS ≥10 µm AND < 50 µm	30/1701
ANALYTICAL METHOD DETERMINATION OF PRIMARY PRODUCTION OF MICROALGAE	30/1702
ANALYTICAL METHOD DETERMINATION OF VIABLE ALGAE BY RE-GROWTH ASSAY	30/1704
MICROBIOLOGICAL TESTS DETERMINATION OF TOTAL NUMBER OF BACTERIA BY EPIFLUORESCENCE MICROSCOPY	30/1705
MICROBIOLOGICAL TESTS DETERMINATION OF HETEROTROPHIC PLATE COUNT	30/1706
MICROBIOLOGICAL TESTS DETERMINATION OF *VIBRIO CHOLERAE* IN WATER	30/1707
MICROBIOLOGICAL TESTS DETERMINATION OF TOTAL COLIFORM, E.COLI AND ENTEROCOCCI BY Colilert*-18, Enterolert-E or Bio-Rad MUG/MUD kit	30/1708
MEASUREMENT METHOD TRO MEASUREMENT IN WATER	30/1732
HARVESTING, CULTURING AND ADDITION OF ORGANISMS	30/1734
COLLECTION OF SEAWATER	30/1735
COLLECTION OF FRESH WATER	30/1736
CRITERIA FOR TEST WATER ADDITION OF DOC, POC, MM AND BRINE	30/1737
SAMPLING PREPARATION, SUBSAMPLING AND TRANSPORTATION OF SAMPLES	30/1738
DATABASE SAMPLES, LABELS AND DATA SHEETS	30/1750
OPERATION OF THE DHI MTEF	30/1762
CLEANING RETENTION TANKS; PIPINGS AND OTHER EQUIPMENT AT TEST SITE	30/1763
MEASUREMENT METHOD ON-LINE MONITORING OF PRESSURE, TEMPERATURE, FLOW RATES AND QUALITY PARAMETERS AT TEST SITE	30/1764
MEASUREMENT METHOD FLUORESCENCE	30/1765
MEASUREMENT METHOD TURBIDITY	30/1766
DHI MTEF HEALTH AND SAFETY	30/1767
MEASUREMENT METHOD DETERMINATION OF TSS	30/1768
MEASUREMENT METHOD DETERMINATION OF DOC AND POC	30/1769
MEASUREMENT METHOD DETERMINATION OF TRANSMITTANCE	30/1770

A P P E N D I X   B

Overview of lists

Overview of lists

The lists mentioned below are kept together with the rest of quality documentation.

Classification society

DHI holds a statement describing the Classification society that has certified the DHI Maritime Technology Evaluation Facility.

List of sub-contractors

DHI keeps a list of sub-contractors used during the test. The list contains information on name of company, address, contact person, e-mail, telephone number and deliveries.

List of project managers

DHI keeps a list of appointed project managers and their experience records. The project manager’s competence is documented in an available CV.

List of staff approved for functions at the test facility

DHI keeps a list of persons working at the test facility. The list contains information on the person’s activities, responsibility and documentation for training. The person’s competence is documented in an available CV.

List of Standard Operating Procedures

DHI keeps a list of DHI SOPs, including those used in relation to projects conducted at the test facility.

A P P E N D I X C

Template for amendments to QAPP

AMENDMENT

AMENDMENT NUMBER

QAPP DOCUMENT TITLE AND MONTH OF ISSUE

DATE OF AMENDMENT

DESSCRIPTION OF AMENDMENT

REASON FOR AMENDMENT

IMPACT OF AMMENDMENT

PREVENTATIVE ACTION

If relevant, action to prevent that the same cause of amendment will occur in the future.

SIGNED BY

____

Project Manager

Copy to be sent to the manufacturer, the classification society or Independent Laboratory and the DHI Quality Assurance Unit.

A P P E N D I X D

Template for deviations to QAPP

DEVIATION

DEVIATION NUMBER

QAPP DOCUMENT TITLE AND MONTH OF ISSUE

DATE OF DEVIATION

DESCRIPTION OF DEVIATION

REASON FOR DEVIATION

IMPACT OF DEVIATION

PREVENTIVE ACTION

If required, actions to be taken to prevent consequences of deviation

SIGNED BY

____
Project Manager

Copy to be sent to the manufacturer, the classification society or Independent Laboratory and the DHI Quality Assurance Unit.

Biological efficacy performance evaluation of the RayClean Ballast Water Management System in shipboard test

Test plan

DESMI Ocean Guard A/S
Test plan
May 2013

This report has been prepared under the DHI Business Management System certified by DNV and specifically for ballast water management system testing certified by Lloyd's Register	
Quality Management	BWMS Testing
ISO 9001	IMO Resolution MEPC.174(58) Annex part 2
Quality Management System certified according to DS/EN ISO 9001 by Det Norske Veritas, Business Assurance, Denmark A/S	Lloyd's Register

Approved by
15-05-2013 X Jens Tørsløv Approved by Signed by: Jens Tørsløv

Biological efficacy performance evaluation of the RayClean Ballast Water Management System in shipboard test

Test plan

Thurø Mærsk

Prepared for DESMI Ocean Guard A/S

Represented by Rasmus Folsø

Project No	11814563
Classification	Confidential

Author	Gitte I. Petersen	Gitte I. Petersen.

QC	Torben Madsen	Torben Madsen

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1 Project description and treatment performance objectives

1.1 Background and objectives

This Test Plan describes the biological efficacy performance evaluation of the ballast water management system (BWMS) in a shipboard test. The Test Plan provides the project specific details, such as the trial periods and locations, whereas the standard procedures and analyses are described in DHI's Quality Assurance Project Plan (QAPP) and the standard operating procedures (SOPs). The QAPP is provided in Appendix A.

DESMI Ocean Guard A/S, manufacturer of the BWMS RayClean, has entered a Contract with DHI on the biological efficacy performance evaluation of the BWMS in a shipboard test.

The mailing address of DESMI Ocean Guard A/S is:

DESMI Ocean Guard A/S
Lufthavnsvej 12
DK-9400 Nørresundby
Denmark

The ballast water discharge standard in Regulation D-2 /1/, which is also known as the IMO D-2 standard, and the U.S. Coast Guard Standards for Living Organisms in Ships' Ballast Water Discharge in U.S. Water (/2/; §151.2030) establish similar discharge standards.

The shipboard test will be conducted with the aim to meet the testing requirements in Resolution MEPC.174(58) /3/, which is generally referred to as the IMO G8 guidelines and the U.S. Coast Guard Standards /2/.

Currently, DHI is not recognized as an Independent Laboratory according to the U.S. Coast Guard standards, and DHI shall not be responsible if this fact is taken into account in the evaluation by U.S. Coast Guard.

1.2 Testing laboratory

The project is conducted by DHI Denmark (www.dhigroup.com) with the following facilities:

Mailing address:

DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark
Att. Torben Madsen

DHI Maritime Technology Evaluation Facility
Færgevejen 18
DK-3390 Hundested
Denmark

1.3 Classification society

The classification society appointed by the manufacturer for inspection and certification of the project is:

Det Norske Veritas A/S (DNV)
Veritasveien 1
NO-1363 Høvik
Norway

2 Project organisation and personnel responsibilities

DHI's project manager for the present BWMS performance evaluation is:

Michael Andersen, M.Sc. Environmental engineer

DHI's project organisation is illustrated in Figure 2.1.

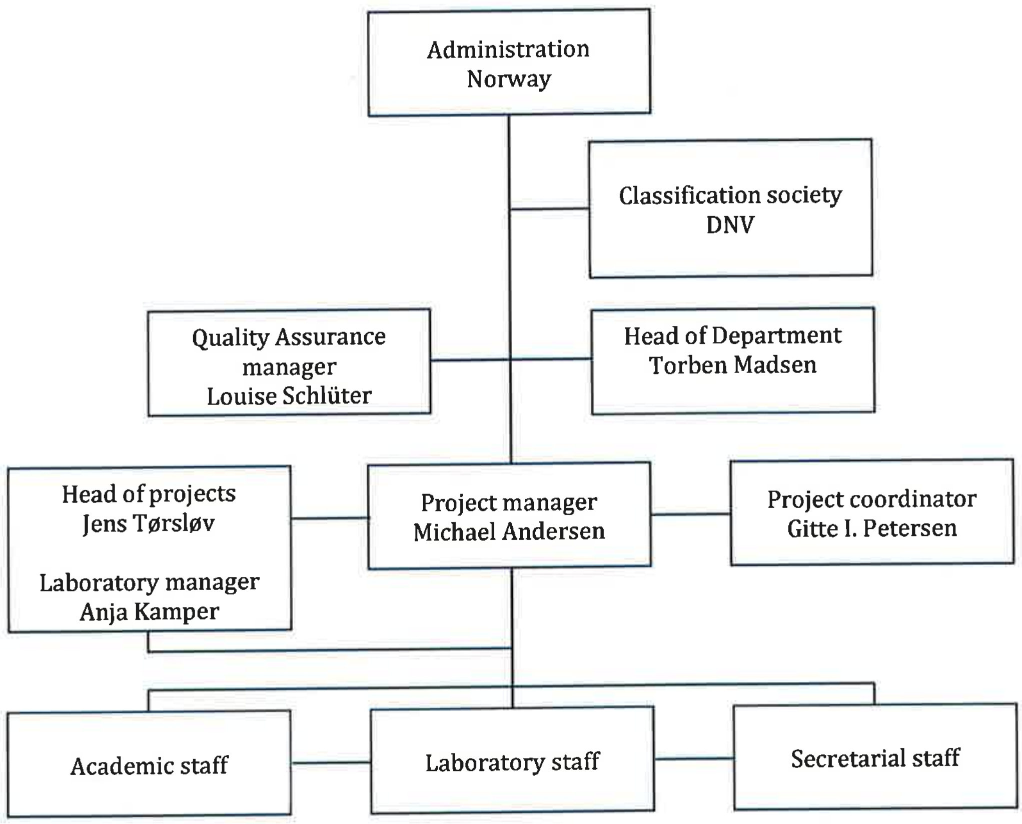

Figure 2.1 DHI's project organisation

A detailed description of the project organisation and the personnel responsibilities is provided in the QAPP.

3 Description of testing laboratory

A detailed description of DHI Denmark and subcontractors that may be performing specific analyses is provided in the QAPP.

4 Description of ballast water management system

4.1 Technology performance claims

DESMI Ocean Guard A/S states that the RayClean BWMS meets the following treatment and operation standards (with reference to the information required in the ETV protocol /4/, Section 3.2).

The BWMS is designed to accomplish the ballast water discharge standard in IMO G8 /2/ and U.S. Coast Guard Standards /3/, §151.2030, which should be supported by quantitative measures of biological treatment efficacy expressed as a concentration upon discharge of the specified organism size classes.

The biological treatment efficacy stated above can be achieved by the following quantitative measures of operational performance (e.g. the allowable and treatable flow rate and other relevant physical conditions):

- Treatment rated capacity for one UV unit: 300 m^3/h

The maritime environmental conditions where the BWMS can be expected to achieve the ballast water discharge standard:

- Salinity range: The BWMS works in any salinity
- Temperature: The BWMS works with water temperatures from 0 to 40°C.
- UV-transmittance: The BWMS works with full flow rate from UVT of 1.0 down to approx. 0.55. Tests will confirm the exact value. UVT levels between 0.55 to approx. 0.33 will cause reduced flow in order to maintain UV dose. Below UVT of approx. 0.33, the system will give an alarm in order to inform that the system is working outside range.

Concentration of disinfection residuals, by-products and toxicity for relevant systems:

- No disinfection residuals, by-products or toxicity are expected in the discharge water.

The required operational and maintenance conditions (operator time, power requirements, chemical consumption requirements, reliability, etc.):

- Please see technology and process description in Appendix C

The projected mean-time between failure for the technology given the operation and maintenance schedules provided for the technology:

- When the given operation and maintenance schedules are adhered to, DESMI Ocean Guard A/S does not expect failures. Projected mean times between failures cannot be estimated on the basis of the limited available experience with long term operation.

The technology and process description including the appropriate sections of the format for the Technical Data Package described in Section 3.10 of the ETV protocol /4/, with safety and environmental hazards and precautions, and photographs or drawings is presented in the System Manual: RayClean Operation Maintenance and Safety Manual. Description of ship and technology is enclosed in Appendix C.

5 Experimental design

5.1 Trial period and locations

The shipboard test will include five (5) BE test cycles conducted during separate campaigns on board the Thurø Mærsk. The campaigns will be conducted within a trial period with a time span of not less than six months.

The campaigns are planned to be conducted between ports at the Iberian peninsula.

The first campaign including one test cycle is scheduled to be conducted in the ports of Lisbon and Leixous, Portugal in week 21, 2013.

The second campaign including two test cycles is scheduled to be conducted in August 2013, or later, and is scheduled to be conducted between ports at the Iberian peninsula. Details on dates and locations for ballasting and deballasting activities will be provided in an amendment to the Test Plan when this information is available.

The third campaign including two test cycles is scheduled to be conducted in November-December 2013 or later. Details on dates and locations for ballasting and deballasting activities will be provided in an amendment to the Test Plan when this information is available.

5.2 Biological efficacy test cycles

The BWMS will be operated by the vessel crew during all BE test cycles. Due to limitations in life saving appliances on the vessel it is uncertain whether DHI personnel will be able to stay on-board the vessel for the entire duration of a BE test cycle. In the case ballast – and de-ballast operations are to be performed in two different ports it may be necessary that DHI personnel disembark after the ballast operation and embark again for the de-ballast operation.

Each test cycle consists of sampling and analyses of:

- **Inlet water** (the physical/chemical and biological parameters in the inlet water will be considered as sufficiently stable during the ballasting; unless the local conditions indicate that the parameters in the inlet water vary with time, only one set of samples and analyses will be used to represent the control tank and the ballast tank).
- **Control discharge water** (stored without treatment from the time of ballasting to discharge)
- **Treated discharge water** (treated and stored from the time of ballasting to discharge).

6 Sampling and analysis plan

6.1 Sample overview

Table 6.1 Overview of samples in shipboard test

Test cycle step	Number of samples	Type of sample	Sample volume per replicate
Inlet water	3 replicates	Organisms ≥50 μm	>1 m^3 *
		Organisms 10-50 μm	>1 L ***
		Bacteria	>0.5 L ***
		DOC, POC, UV-T	Approx. 0.5 L ***
		TSS	0.5-2 L ***
Control discharge water	3 replicates	Organisms ≥50 μm	>1 m^3 *
		Organisms 10-50 μm	>1 L ***
		Bacteria	>0.5 L ***
		DOC, POC	Approx. 0.5 L ***
		TSS	0.5-2 L ***
Treated discharge water	3 replicates	Organisms ≥50 μm	>3 m^3 *
	3 replicates	Organisms 10-50 μm	>3 L **
	3 × 3 replicates	Bacteria	>0.5 L ***
	3 replicates	DOC, POC	Approx. 0.5 L ***
	3 replicates	TSS	0.5-2 L ***

* Collected by continuous flow during the entire period of intake or discharge; for treated discharge, this time integrated continuous sampling of 3 replicates, each of a volume of >3 m^3, provides the same statistical basis for evaluation as the sampling 3 × 3 replicates of >1 m^3, which is recommended in the G8 guidelines

** Collected by continuous flow during the entire period of discharge; for treated discharge, this time integrated continuous sampling of 3 replicates, each of a volume of >3 L, provides the same statistical basis for evaluation as the sampling 3 × 3 replicates of >1 L, which is recommended in the G8 guidelines

*** Grab samples collected over the period of intake or discharge (e.g. start, middle and end)

6.2 Samples for enumeration of organisms ≥50 μm

Three replicates will be collected by parallel continuous sampling during the entire periods of intake and discharge. The samples will be gently filtered through a net with a mesh size of 35 μm and a reservoir (cod-end) at the bottom of the net for collecting the organisms. Each replicate will be concentrated in 1-L glass bottles. The total volume of the filtered sample will be determined by a flow meter.

6.3 Samples for enumeration of organisms ≥10 μm and <50 μm

Grab samples will be collected for the inlet water and for the control discharge water (3 replicates each), each with a volume of at least 1 L. Treated discharge water will be collected by continuous flow during the entire period of discharge with a volume of at least 3 L each. The samples will be collected in appropriate containers.

6.4 Samples for enumeration of organisms <10 μm

Grab samples (3 replicates for the inlet water, 3 replicates for the control discharge water and 3 × 3 replicates for the treated discharge water) with a volume of at least 0.5 L will be collected in appropriate sterile containers with sodium thiosulfate.

7 Data management, analyses and reporting

7.1 Data management

The recording and storage of data are described in the QAPP. A data logging format to be used on board the vessel during each BE test cycle is included in Appendix B.

Documentation according to §162.060-28 (i) of the U.S. Coast Guard Standards for Living Organisms in Ships' Ballast Water Discharge in U.S. Waters /2/ during the entire period of RayClean shipboard testing operations conducted on the vessel is the responsibility of the DESMI Ocean Guard. DHI will collect the information relevant for the BE test cycles when DHI staff is present during BE testing (volumes, operation times, flow rates, locations etc.). DHI is only present during BE test cycles and will thus not be accountable for documenting continuous activities regarding the RayClean installation onboard the vessel (for example scheduled/unscheduled maintenance of the RayClean, weather conditions and resultant effects, consumption of solutions, preparations or consumables, instrument calibration etc.).

7.2 Analyses

7.2.1 Analyses overview

Table 7.1 Overview of analyses in shipboard test

Samples and replicates	Organisms ≥ 50 µm	Organisms ≥10-<50 µm, microscopy	Organisms ≥10-<50 µm, algal re-growth	Organisms <10 µm	Temperature, salinity, turbidity	UV transmittance	DOC + POC	TSS
Inlet water								
Rep 1 (start)	Three continuous replicates	1	1	1	1	1	1	1
Rep 2 (mid)		2	2	2	2	2	2	2
Rep 3 (end)		3	3	3	3	3	3	3
Control discharge water								
Rep 1 (start)	Three continuous replicates	1	1	1	1	-	1	1
Rep 2 (mid)		2	2	2	2	-	2	2
Rep 3 (end)		3	3	3	3	-	3	3
Treated discharge water								
Rep 1-3 (start)	Three continuous replicates	1	1	1-3	1	1	1	1
Rep 4-6 (mid)		2	2	4-6	4	2	4	4
Rep 7-9 (end)		3	3	7-9	7	3	7	7

The samples for all analyses will be kept cool from the time of collection, and the samples will be processed for analyses within the shortest possible time period.

7.2.2 Organism size class ≥50 µm

Compliance with the pass criterion (Appendix A, QAPP, Chapter 9) will be verified by use of the direct count of organisms ≥50 µm in minimum dimension.

The concentrations of live organisms ≥50 μm in minimum dimension will be determined by use of a stereo microscope and a counting chamber according to DHI SOP 30/1700. Live organisms will be enumerated by use of standard movement and response to stimuli technique. The live organisms will be characterized according to major taxonomic groups. The analyses will be completed on location.

7.2.3 Organism size class ≥10 μm and <50 μm

Compliance with the pass criterion (Appendix A, QAPP, Chapter 9) will be verified by use of the total of viable organisms determined by measuring algal re-growth in a most probable number (MPN) assay and enumeration of viable organisms ≥10 μm and <50 μm in minimum dimension that are not encompassed by the algal re-growth assay (i.e. organisms without chlorophyll labelled with chloromethylflourescein diacetate (CMFDA) or fluorescein diacetate (FDA)).

Work on location

Samples preserved with Lugol's solution. Inlet samples will be preserved with Lugol's solution to enable determination of the concentrations of organisms in the size class ≥10 and <50 μm. The container with water sample will be shaken gently (upside down 5 times) and subsamples with an approx. volume of 100 mL will be transferred to brown glass bottles. Two subsamples will be collected for one replicate and one subsample will be collected for the remaining two replicates. Lugol's solution will be added to achieve a final concentration of 2% according to DHI SOP 30/1701.

Samples for CMFDA/FDA analysis. The container with the total sample will be shaken gently (upside down 5 times). Subsamples with an approx. volume of 100 mL will be transferred to brown glass bottles. Two subsamples will be collected for one replicate and one subsample will be collected for the remaining two replicates. These subsamples will be stored in the dark and transported to the DHI Environmental Laboratory for further analysis.

Algal re-growth assay. The concentrations of viable algae in the inlet and discharge water samples will be analysed by measuring algal re-growth in a most probable number (MPN) assay. The container with the total sample will be shaken gently (upside down 5 times). One subsample (approx. 10 mL) of undiluted water per replicate will be kept in the dark as 'back-up samples'. Dilution series of the inlet water, control discharge water and treated discharge water will be prepared by adding 1-mL aliquots of sample to test tubes with 5 mL of liquid medium as described in DHI SOP 30/1704. Ten (10) control test tubes containing only 5 mL of medium will be prepared. The test tubes will be kept in the dark until arrival at the DHI Environmental Laboratory.

Work in laboratory

Samples preserved with Lugol's solution. These samples will be analysed as follows:

- **Inlet water**. Assuming that practically all of the organisms in the natural water are living, fulfilment of the validity criterion for the concentration of organisms ≥10 and <50 μm in the inlet water will be confirmed by inverted microscopy enumeration according to DHI SOP 30/1701. The analyses comprise detailed examination of the algal chloroplasts to confirm that the phytoplankton was alive and classification of the algae according to groups, taxa or species.
- **Control discharge water**. Inverted microscopy enumeration will be applied to confirm that the validity criterion for the concentration of organisms ≥10 and <50 μm in the control discharge water is fulfilled.
- **Treated discharge water**. Inverted microscopy will be applied to quantify the predominant groups, taxa and species ≥10 and <50 μm in the treated discharge water with the purpose to add to the documentation of the algal re-growth assay (see below).

CMFDA/FDA. CMFDA and FDA will be added to a subsample and, after incubation, the subsample will be examined by use of a microscope under epifluorescence. Organisms labelled by either CMFDA or FDA will be considered viable as described in DHI SOP 30/1701. Only CMFDA/FDA labelled moving organisms without chlorophyll are included in the verification of compliance with the pass criterion.

Algal re-growth assay. Upon arrival to the laboratory, the fluorescence of the test tubes will be determined before incubation (t_0). The test tubes will be incubated for 14 days at ambient temperature as described in DHI SOP 30/1704. The concentrations of viable algae in the inlet water, control discharge water and treated discharge water will be determined by measuring the fluorescence in the test tubes according to DHI SOP 30/1704.

The algal re-growth assay will be documented by the growth of the naturally occurring algae under the conditions applied in the assay. Identification of groups, taxa or species in the local water capable of growth under the applied conditions will be performed with undiluted inlet water and after serial dilution. In addition, the algal groups, taxa or species in the inlet water will be thoroughly analysed and compared with the list of algae capable of growing under the conditions in the algal re-growth assay, which has been obtained during land-based testing in Hundested, Denmark and in shipboard test cycles (some of the groups, taxa or species may be the same across geographic regions). DHI is confident that the algal re-growth assay is conducted with conditions that support the growth of a versatile range of algal species. However, the limited number of test cycles (1 or 2) conducted during a shipboard test voyage implies that the list of algae identified in the inlet water and in the algal re-growth assay will be less comprehensive compared with the list obtained from the large number of test cycles in Hundested.

The algal groups, taxa and species in the Lugol's solution preserved inlet water samples will be compared with the identified algae capable of growing under the conditions in the algal re-growth assay. This comparison will enable the confirmation or rejection of whether the predominant groups, taxa or species in the inlet samples are able to grow under the conditions in the assay.

7.2.4 Organism size class <10 μm (bacteria)

Compliance with the pass criterion (Appendix A, QAPP, Chapter 9) will be verified by use of the colony forming units (CFU) enumerated on solid media. The methods for counting of bacteria are described in the QAPP.

Work on location

E. coli and enterococci will be determined according to DHI SOP 30/1708.

For detection of *Vibrio cholerae*, one sample per replicate will be filtered through a 0.45-μm-filter, after which the filter will be kept moist in sterile polyethylene tubes.

Work in laboratory

The possible occurrence of *Vibrio cholerae* will be analysed according to DHI SOP 30/1707.

7.2.5 Physical/chemical analyses

The physical/chemical analyses conducted during the shipboard test include:

- Temperature
- Salinity
- Dissolved oxygen
- pH
- Turbidity
- UV transmittance (UV-T)
- Dissolved organic carbon (DOC)
- Particulate organic carbon (POC)
- Total suspended solids (TSS)

Work on location
Temperature, salinity, dissolved oxygen, pH and turbidity will be measured by use of portable instruments equipped with electrodes. Measurements will be conducted at regular intervals throughout the inlet and discharge operations.

For determination of DOC and POC, the samples will be treated as described in DHI SOP 30/1769. For determination of TSS, the samples will be filtered through a glass fibre filter, which has already been weighed in the laboratory as described in DHI SOP 30/1768. For determination of UV-T, a subsample with a volume of 100-200 mL for each replicate will transferred to glass bottles and kept in the dark until arrival at the DHI Environmental Laboratory.

Work in laboratory
Determination of DOC and POC will be performed according to DHI SOP 30/1769. Determination of TSS will be performed according to DHI SOP 30/1768. Determination of UV-T will be performed according to DHI SOP 30/1770.

7.3 Reporting

The following reports will be prepared:

- Interim reports compiling the data from the first and the second campaign
- Draft final report compiling all relevant data from the test cycles, data interpretation and conclusion
- Final report

8 Amendments and deviations

Amendments are planned changes to the Test Plan. Deviations are unplanned changes. Amendments and deviations will be signed by the project manager and documented in the file and the final report.

9 Shipboard testing requirements

The BWMS must comply with all requirements stated in Resolution MEPC.174(58) (Annex, Part 2, Section 2.2) /3/, and the U.S. Coast Guard Standards (§162.060-28) /2/.

Specifically for the biological efficacy performance evaluation, the BE test cycles must be conducted throughout a period of operation of at least six months.

Resolution MEPC.174(58), which is also referred to as the IMO G8 guidelines /3/, prescribes that the biological efficacy performance evaluation in the shipboard test may be considered successful, if the results of three (3) consecutive, valid test cycles show discharge of treated ballast water in compliance with Regulation D-2 /1/ (see Appendix A, QAPP, Chapters 8-9).

The U.S. Coast Guard Standards /2/ prescribe that the biological efficacy performance evaluation in the shipboard test may be considered successful, if the results of five (5) consecutive, valid test cycles show discharge of treated ballast water in compliance with the ballast water discharge standard (/3/; §151.2030) which is equivalent to Regulation D-2 /1/ (see Appendix A, QAPP, Chapters 8-9).

10 Time schedule

21-23 May 2013:

- Campaign 1. One BE test cycle conducted on board

15 July 2013:

- Interim report, Campaign 1

August- 2013 or later:

- Campaign 2. Two BE test cycles conducted on board. Interim report submitted one month after completion of Campaign 2

November-December 2013 or later:

- Campaign 3. Two BE test cycles conducted on board

January-February 2014:

- Draft and final reporting. Final report submitted two months after completion of the third campaign

31 May 2014:

- Completion date

11 References

/1/ IMO. International Convention for the Control and Management of Ships' Ballast Water and Sediments. London. International Maritime Organization, 2004.

/2/ U.S. Coast Guard. Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters. Federal Register, Vol. 77, No. 57, March 23, 2012.

/3/ MEPC. Guidelines for Approval of Ballast Water Management Systems (G8). Resolution MEPC.174(58). Adopted 10th October 2008.

/4/ U.S. Environmental Protection Agency, Environmental Technology Verification Program. Generic Protocol for the Verification of Ballast Water Treatment Technology. EPA/600/R-10/146, September 2010.

Approval of Test Plan

DHI Denmark

Project management Date: 2013.05.15

Michael Andersen

Quality control Date: 2013.05.15

Torben Madsen

This Test Plan is accepted and my signature authorizes the study to proceed as described in this document.

Manufacturer Date: 2013.05.15

Rasmus Folsø
DESMI Ocean Guard A/S

APPENDIX A

Quality Assurance Project Plan

Biological efficacy performance evaluation of Ballast Water Management Systems

Quality Assurance Project Plan

Version 2.2
March 2013

This report has been prepared under the DHI Business Management System certified by DNV and specifically for ballast water management system testing certified by Lloyd's Register	
Quality Management	BWMS Testing
ISO 9001	IMO Resolution MEPC.174(58) Annex part 2
Quality Management System certified according to DS/EN ISO 9001 by Det Norske Veritas, Business Assurance Denmark A/S	Lloyd's Register

Approved by

18-03-2013

X

Approved by

Signed by: Torben Madsen

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Appendices

A Certificate of compliance, ISO 9001 certificate, accreditation and GLP authorisation
B Overview of DHI SOPs

Abbreviations

Abbreviation	Description
BE	Biological efficacy
BWMS	Ballast water management system
CFU	Colony forming units
CMFDA	Chloromethylfluorescein diacetate
DANAK	Danish Accreditation and Metrology Fund
DNV	Det Norske Veritas
DOC	Dissolved organic carbon
DOM	Dissolved organic matter
DQI	Data quality indicators
FDA	Fluorescein diacetate
IMO	International Maritime Organization
ISPS	International Safety Port System
kVA	Kilovolt-ampere
MEPC	Marine Environment Protection Committee
MM	Mineral materials
MPN	Most probable number
O&M	Operation and maintenance
POC	Particulate organic carbon
POM	Particulate organic matter
PSU	Practical salinity units
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
QMP	Quality Management Plan
SOP	Standard operating procedure
TSS	Total suspended solids
WET	Whole effluent toxicity

1 Project description and treatment performance objectives

1.1 Background and objectives

For an application for final approval, the IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments /1/ requires a performance evaluation of ballast water management systems (BWMS) according to the principles laid down in Resolution MEPC.174(58) /2/, generally referred to as IMO G8 guidelines, and, for systems that make use of active substances, also Resolution MEPC.169(57) /3/, generally referred to as IMO G9 guidelines. The purpose of the performance evaluation is to assure that BWMS approved by administrations are capable of meeting the ballast water performance standard in Regulation D-2 /1/, also known as the IMO D-2 standard, in land-based and shipboard evaluations and do not cause unacceptable harm to the vessel, crew, environment or public health. The U.S. Coast Guard Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters /4/ (§151.2030) establish a ballast water discharge standard similar to the IMO D-2 standard. According to the U.S. Coast Guard the test set up in land-based test cycles of BWMS must operate as described in the ETV protocol /5/.

1.2 Testing laboratory

The project is conducted by DHI Denmark (www.dhigroup.com) with the following facilities:

Mailing address:

DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark
Att. Torben Madsen

DHI Maritime Technology Evaluation Facility
Færgevejen
DK-3390 Hundested
Denmark

DHI Denmark and its facilities are described in detail in Chapter 3.

2 Project organisation and personnel responsibilities

DHI's project organisation is illustrated in Figure 2.1.

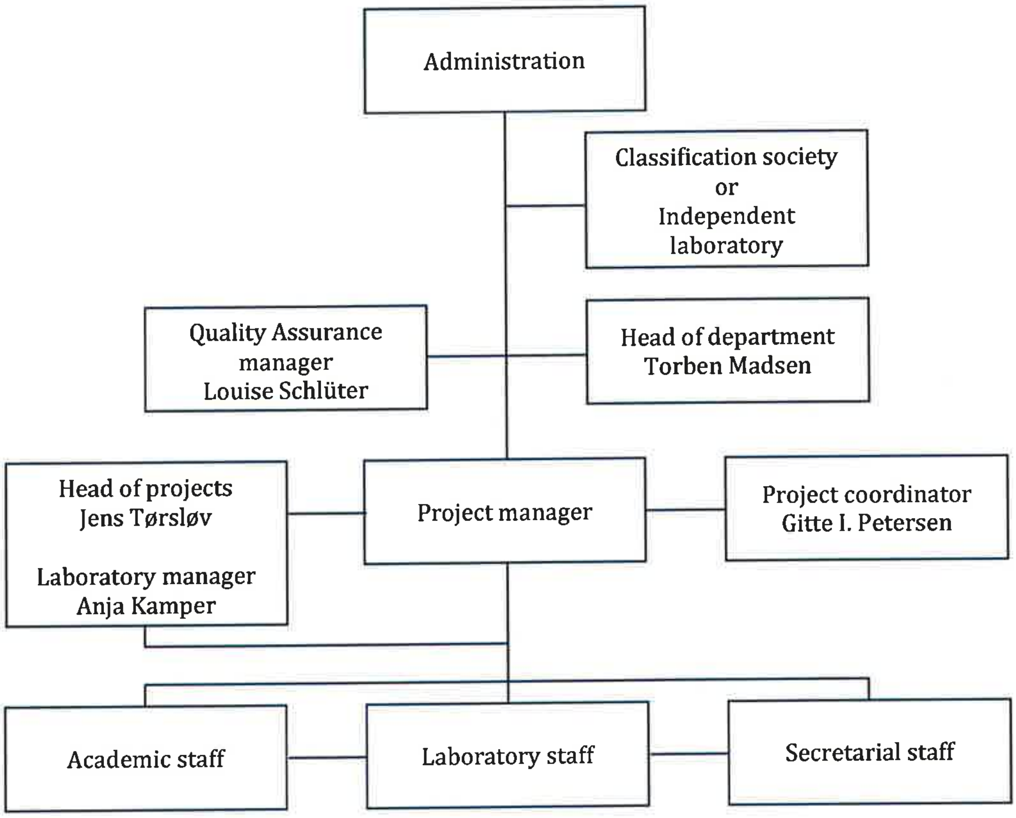


Figure 2.1 The DHI project organisation

2.1 Quality Assurance manager

Senior biologist Louise Schlüter (Ph.D.) is assigned by DHI's Quality Assurance (QA) unit as internal auditor (see Chapter 10). This includes the following tasks:

- Drafting of a plan for quality assurance
- Monitoring of compliance with the Quality Management Plan (QMP), the Quality Assurance Project Plan (QAPP), the Test Plan and the standard operating procedures (SOPs) by audit including the project manager and the laboratory staff
- Monitoring compliance with the appropriate guidelines or standards by audit including the project manager
- Verification of the presence of applicable staff training records
- Drafting of audit reports and verification that audit responses are appropriate and that corrective action has been implemented effectively
- Verification that the final product complies with DHIs standards for QA (Chapter 10) and, particularly, the QMP, the QAPP, the Test Plan and the guidelines and standards

2.2 Head of department

Head of department Torben Madsen (Ph.D.) is quality supervisor for all projects and has the overall responsibility for the services related to performance evaluation of BWMS provided by DHI Denmark. This includes the following tasks:

- Member of the Ballast Water Test Facility Board for DHI Ballast Water Centre, a coordinating structure between DHI Denmark and DHI Singapore

- Overall responsibility for the test facility and the DHI Environmental Laboratory including health and safety in the work place and decisions on investments and maintenance expenses
- Overall responsibility for the liaison and contractual relations between DHI and Lloyds Register EMEA (certification of test facility), between DHI and the Danish Accreditation and Metrology Fund, DANAK (accreditation of analyses), and between DHI and the Independent Laboratory (subcontractor agreement)
- Negotiation of contracts with manufacturers (or clients)
- Appointment of project managers and staff responsible for quality control (QC) of individual data (data-level QC) and maintenance of staff experience records (allocation of project managers for specific projects is the responsibility of the head of projects)
- Maintenance of the QAPP and the QMP /6/ with updated versions as appropriate
- Quality control of the QAPP, Test Plan, SOPs and all project proposals, deliverables and reports
- Documentation in relation to
    - Staff training and experience
    - Facilities and their maintenance
    - Records of complaints

2.3 Project coordinator

Business area manager Gitte I. Petersen (Ph.D.) is responsible for the coordination, timely execution and the overall scientific quality of the services. This includes the following tasks:

- Business development and marketing
- Contact and dialogue with Lloyds Register EMEA prior to inspections and for management of the actions and documentation, in collaboration with the laboratory manager, as required to comply with the Certificate of Compliance issued by Lloyds Register EMEA
- Contact and dialogue with the Independent Laboratory prior to inspections and for management of the actions and documentation, in collaboration with the laboratory manager, as required to comply with the agreement between DHI and the Independent Laboratory
- Coordination of the services to ensure optimal logistics at the test facility, including decisions related to the practical installation of manufacturers and their technology and timing of tests
- Maintenance of the test facility including routine technical maintenance and dialogue with the head of department in relation to investments and maintenance expenses
- Instruction of staff with responsibility for specific tasks such as test facility technical operations and production of test water
- Principal scientific expert with responsibility for the overall scientific quality of the services, including compliance with official guidelines, standards, protocols and requirements from classification societies and Independent Laboratories; this implies input to the QAPP and the Test Plan, revisions and implementation of SOPs, and contributions to data interpretation and reporting in collaboration with the project manager
- Participation in discussions with the classification society or the Independent Laboratory on important matters, particularly draft and final reports, together with the project manager

2.4 Head of projects and laboratory manager

Head of projects Jens Tørsløv (Ph.D.) has the overall responsibility for allocation of staff, planning and project execution in coordination with the project coordinator or the project manager as appropriate.

Laboratory manager Anja Kamper (M.Sc.) allocates laboratory technicians for specific projects as part of the laboratory capacity planning by allocation of responsibility from the head of projects. Furthermore, the laboratory manager appoints one or more test coordinators among the laboratory technicians or the academic staff for on-site coordination of land-based test cycles.

The laboratory manager is responsible for the contact and dialogue with DANAK prior to inspections and for management of the actions and documentation as required to comply with the ISO 17025 accreditation /7/.

2.5 Project manager

The project manager is responsible for the management and efficient performance of the project in accordance with the Contract between the manufacturer and DHI, the QMP, the QAPP and the Test Plan.

The project manager's tasks include:

- Organisation and management of the project
- Meetings and other communication with the manufacturer to ensure that all necessary information is available in due time
- Preparation of the draft and final Test Plan with detailed description of the project, including time schedule of activities and deliverables; the QAPP and the Test Plan shall be made available to all staff participating in the project
- Facilitation of the process for comments and responses to the QAPP and the draft Test Plan in dialogue with the manufacturer and the classification society or the Independent Laboratory
- Preparation of potential amendments and deviations to the Test plan
- Communication of the project time schedule to the classification society or the Independent Laboratory to enable external audit
- Participation in discussions with the classification society or the Independent Laboratory on important matters, particularly draft and final reports, together with the Project Coordinator
- Coordination and dialogue with the laboratory manager in relation to the practical organisation of work involving laboratory technicians; the project manager shall in due time inform the laboratory manager of the types of tests and the required capacity to enable laboratory capacity planning
- Contracts with subcontractors (e.g. chemical analytical laboratory) as appropriate for meeting the project deliverables
- Approval of initiation of the test cycles and interruption of test cycles, e.g. in case of irregularity
- Preparation of reports

2.6 Academic, laboratory and secretarial staff

The tasks of the academic, the laboratory and the secretarial staff include:

- Maintenance of materials and equipment
- Test facility technical operations
- Test coordinator function, i.e. coordination and keeping of timely records of the activities at the test facility during land-based tests
- Production of test water and monitoring of test water quality
- Sampling at the test facility
- Analysis and data processing, including data-level QC
- Contributions to test reports
- Archiving of documents and raw data
- Contributions to QAPPs, Test Plans and SOPs

2.7 Manufacturer

The tasks of the representative of the manufacturer include:

- Signing a Contract with DHI for the BWMS performance evaluation project
- Project management of the manufacturers activities in the project, including the liaison with DHI and decisions in relation to the testing
- Review and comments to the draft Test Plan and approval of the final Test Plan
- Collaboration with DHI to establish all necessary arrangements prior to initiation of the test
- Review and comments to draft test reports
- Dismantling and removal of the BWMS from the test facility after ended testing

3 Description of testing laboratory

3.1 DHI Denmark

DHI is an independent, international consulting and research organisation established in Denmark and today represented in all regions of the world with a total of more than 1,000 employees. Our objectives are to advance technological development, governance and competence in the fields of water, environment and health. DHI works with governmental agencies and authorities, contractors, consultants and numerous industries.

DHI has no involvement, intellectual or financial, in the mechanics, design or marketing of the products and technologies that are being evaluated. To ensure that DHI's tests are uncompromised by any real or perceived individual or team bias relative to test outcomes, DHI's test activities are subject to rigorous quality assurance (QA), quality control (QC) and documentation.

DHI's quality management system is certified according to ISO 9001 by DNV (Det Norske Veritas). The certification is facilitated by the implementation of the DHI Business Management System (see Chapter 10).

3.2 DHI Environmental Laboratory

DHI's Environmental Laboratory has an accreditation according to ISO 17025 /7/ which includes ecotoxicological studies and analyses related to the performance evaluation of BWMS. Furthermore, the laboratory is authorized to carry out ecotoxicological studies in compliance with the OECD Principles of Good Laboratory Practice (GLP) /8/.

DHI's Environmental Laboratory and staff normally analyse all samples collected during the performance evaluation of BWMS. If required, specialized chemical analyses of, e.g., active substances or disinfection by-products, are conducted by a subcontractor identified in the section on Subcontractors.

3.3 DHI Maritime Technology Evaluation Facility

DHI holds a Certificate of Compliance issued by Lloyd's Register EMEA for the performance of land-based and shipboard testing of BWMS (Appendix A).

The travel time from the DHI Maritime Technology Evaluation Facility to the DHI Environmental Laboratory is approx. 50 min, which enables analysis or treatment of the samples within 6 hours.

The test facility is used to conduct biological evaluations of maritime technologies. The test facility is covered by the International Safety Port System (ISPS). Hundested Harbour is registered at the IMO's website (Port facilities) under Port ID No. 266076DKHUN, Port facility 1651.

The test facility includes seven cylindrical tanks constructed in galvanized steel and coated with a non-toxic top coating:

- One open 750-m^3 source tank, Tank D in Figure 3.1. The source tank is equipped with a propeller, which creates a slow circulation in order to maintain the homogeneity of the test water. A bridge across the top of the source tank is established for monitoring the homogeneity.
- Six closed 250-m^3 retention tanks, Tanks A1, B1, C1, A2, B2 and C2 in Figure 3.1. Tanks A1 and A2 are also described as 'control tanks' and are used for untreated test water. Tanks B1, C1, B2 and C2 are retention tanks for treated test water. Each of the six retention tanks is equipped with a submersible agitator (with three-blade propeller) giving the possibility to create a slow circulation in order to maintain homogeneity of the test water.

The piping connecting source tank, control tanks, retention tanks, pump and BWMS is made of polyethylene. The diameters are 315 mm and 350 mm for the piping connecting the A1, B1 and C1 tanks and 400 mm and 500 mm for the piping connecting the A2, B2 and C2 tanks.

The piping system connecting the source tank and the retention tanks is equipped with sampling ports. The sampling ports are equipped with the following sample outlets:

1. Sample outlet for ≥1-m^3 samples (to be used for analysis of organisms ≥50 µm)
2. Sample outlet for ≥10-L samples (to be used for analysis of organisms ≥50 µm and organisms ≥10 to <50 µm)
3. Sample outlet for microbiology samples
4. Sample outlet for samples for analysis of dissolved organic carbon (DOC), particulate organic carbon (POC), total suspended solids (TSS) and transmittance

The test facility is equipped with sensors for automatic logging of flow, pressure, water levels, temperature, dissolved oxygen, pH, salinity and turbidity.

The test facility includes a main pump with a flow performance of 250-500 m^3/hour. By use of a harbour piping, this pump can be used to provide a continuous flow of brackish water directly from the harbour to the BWMS with a capacity of up to approx. 300 m^3/hour. Furthermore, the test facility includes electrical generator power supply up to 150 kVA.

If needed to fulfil the test water quality requirements, appropriate volumes of cultivated organisms can be added to the source tank by an auxiliary pump.

The exact configuration of the test facility piping and equipment may be subject to minor changes.

The procedures, guidelines or characteristics for analyses, operations or tests performed in the DHI Environmental Laboratory, at the test facility or on board a vessel are described in the DHI SOPs.

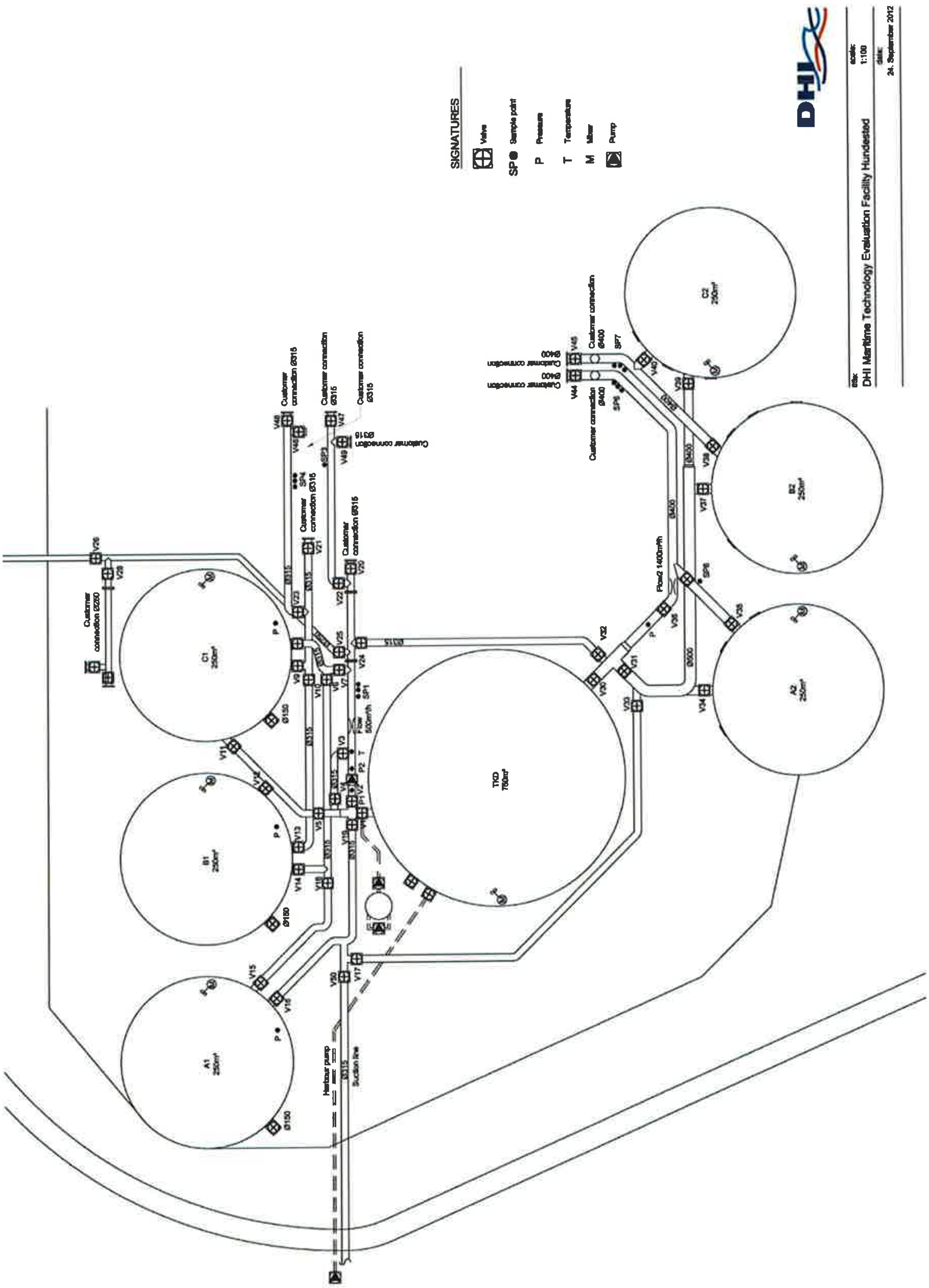


Figure 3.1 DHI Maritime Technology Evaluation Facility, Hundested, Denmark

3.4 Test facility equipment and calibration programmes

Test facility equipment used for analysis of physical-chemical and biological parameters is included in the ISO 17025 accreditation of DHI's Environmental Laboratory. The procedures and frequency for the calibration specific equipment are described in DHI SOPs, and compliance of the equipment with the DHI SOPs is inspected regularly by DANAK.

The test facility is equipped with an on-line monitoring system consisting of several sensors for monitoring of pressure, temperature, flow rate and water quality parameters (Table 3.1).

Table 3.1 Specification of sensor and monitoring equipment at the test facility

No.	Function	Location	Name	Range	Serial No.	Supplier
1	Determination of water level	Bottom of source water tank D	Klay 8000-D-S-I.	0-7.5 mwc*	10204262	Gustaf Fagerberg A/S
2	Determination of water level	Bottom of retention tank C1	Klay 8000-C-S-I.	0-5.4 mwc*	10204265	Gustaf Fagerberg A/S
3	Determination of water level	Bottom of retention tank B1	Klay 8000-C-S-I.	0-5.4 mwc*	10204264	Gustaf Fagerberg A/S
4	Determination of water level	Bottom of retention tank A1	Klay 8000-C-S-I.	0-5.4 mwc*	10204263	Gustaf Fagerberg A/S
5	Determination of water level	Bottom of retention tank C2	Klay 8000-C-S-I.	0-6.0 mwc*	10304331	Gustaf Fagerberg A/S
6	Determination of water level	Bottom of retention tank B2	Klay 8000-C-S-I.	0-6.0 mwc*	10310814	Gustaf Fagerberg A/S
7	Determination of water level	Bottom of retention tank A2	Klay 8000-D-S-I.	0-7,5 mwc*	10304330	Gustaf Fagerberg A/S
8	Determination of pressure in pipes before pump	P1	Klay 8000-E-S-I	0-3.0 bar	10204259	Gustaf Fagerberg A/S
9	Determination of pressure in pipes after pump	P2	Klay 8000-F-S-I	0-4,5 bar	10307332	Gustaf Fagerberg A/S
10	Determination of pressure in pipes after pump	P22	Klay 8000-F-S-I	0-4,5 bar	10304329	Gustaf Fagerberg A/S
11	Determination of pumping flow	Flow	Krohne DN300 Optiflux 2100C with electromagnetig flow converter (IFC100)	0-600 m^3/h	A0991632	Gustaf Fagerberg A/S
12	Determination of temperature in pipes	T	Inor RBS10 PT100 (66RBS10)	0-50°C	v033682 20101042 350120-1	Gustaf Fagerberg A/S
13	Determination of pumping flow	Flow2	Krohne DN400 Optiflux 2000 with electromagnetig flow converter (IFC100)	0-1400 m^3/h	A1094864	Gustaf Fagerberg A/S
14	Determination of pH, temperature, salinity, dissolved oxygen and turbidity before treatment and control discharge	WQ.intake: Sonde equipped with flow chamber connected at relevant sampling point	YSI 6600 V2 data sonde: • 6561 pH sensor • 6150 ROX optical dissolved oxygen sensor • 6136 turbidity sensor	n.a.	11C 101786	YSI inc.
15	Determination of pH, temperature, salinity, dissolved oxygen and turbidity after treatment	WQ.treated: Sonde equipped with flow chamber connected at relevant sampling point	YSI 6600 V2 data sonde: • 6561 pH sensor • 6150 ROX optical dissolved oxygen sensor • 6136 turbidity sensor	n.a.	11C 101787	YSI inc.

* Meter water column

All sensor signals are recorded via 3 Advantech ADAM-6024 modules. Each of these modules can accept 6 analogue input signals (user defined as 0/4-20 mA or ±10 volt), 2 digital input signals, 2 analogue outputs (user defined as 0/4-20 mA or ±10 volt), and 2 digital out-puts. Sensor readings are transferred to an industrial PC type (i-PC) Advantech UNO-2182 running Windows XP sp3. The i-PC is connected to the internet through a 3G modem Huawei B970. The measured data are transferred to an SQL-database running on the PLCSQL server. In the case that the i-PC loses connection to the database-server, the data will be buffered on the i-PC until connection is re-established. Once a day, backup of the database is performed and the backup file is stored on a RAID-5 NAS disk-array placed in another building than the server itself. The client server data management software program DIMS (developed by DHI) is used for handling and storage of the data.

Quality control of the on-line monitoring system is conducted by the activities described below.

The sensor for monitoring of the water level in the source tank (Tank D) is verified by measuring the height of the water columns at maximum and minimum water levels compared to the results from the sensor. Deviations of 3% and 5% are accepted at maximum and the minimum water levels, respectively.

The flow meter is verified by comparing the measured water levels in the tanks with the measured flow. A deviation of 8% is accepted. The control is performed after the sensors for determining the water level have been verified.

The pressure transmitters for monitoring the pressure in the piping are verified by reading the pressure at the maximum and the minimum water levels in the source tank (Tank D) with open piping between the transmitters and the source tank and with a closed valve behind the pressure transmitters. The monitored pressure is compared with the difference in water heights. Deviations of 3% and 5% are accepted at maximum and the minimum water level, respectively.

The thermo sensor is verified by comparing the recorded result with the temperature measured with a traceable thermometer in a time-equivalent flowing sample. A deviation of 1.0°C is accepted.

The water quality sensors are verified by checking the readings in the relevant standard solution. The following deviations are accepted: ±0.2 units for pH, 3% for dissolved oxygen, 5% for turbidity and 2% for conductivity. Verification of dissolved oxygen measurements can also be conducted by comparison between sensors and a calibrated dissolved oxygen meter. All of the water quality sensors require periodic calibration to assure high performance. The calibration is conducted at least every second week by use of the relevant standard solution.

Data for all relevant parameters are extracted from the on-line monitoring system and evaluated after each test cycle. The sensors are adjusted and calibrated again in case of non-compliance with the acceptance criteria.

3.5 Subcontractors

Chemical analyses:
MILANA A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk, Denmark

Microbiology; verification of *Vibrio cholerae* according to DHI SOP 30/1707:

Statens Serum Institut
Artillerivej 5
DK-2300 København S
Denmark

4 Description of ballast water management system

A complete description of the BWMS is provided in the Test Plan.

5 Performance evaluation in land-based test

5.1 Experimental design

5.1.1 Overview of test parameters

DHI's land-based test applies high quality facilities and state-of-the-art methods. A comparison of DHI's test parameters with the requirements of the IMO G8 guidelines /2/ and the ETV protocol /5/ is presented in Table 5.1.

Table 5.1 Comparison of test parameters applied by DHI and the requirements in the IMO G8 and ETV protocol

Parameter	Sub-category	IMO G8	ETV protocol	DHI
Organisms to be evaluated	Zooplankton, live organisms ≥ 50 µm in size	Naturally occurring, or cultured organisms may be added to the test water.	Ambient assemblage supplemented by the addition of standard test organisms.	Naturally occurring in the harbour outside the test facility (brackish and marine) and in Lake Arresø (fresh). For brackish and marine tests, enhanced density of natural organisms can be obtained by collection of backwash from a 10 µm mesh low pressure filter; in addition cultured organisms can be added if required.
	Protists, live organisms 10-50 µm in size	Naturally occurring, or cultured species that may be added to the test water.	Ambient assemblage supplemented by the addition of standard test organisms.	Naturally occurring in the harbour outside the test facility (brackish and marine) and in Lake Arresø (fresh). For brackish and marine tests, enhanced density of natural organisms can be obtained by collection of backwash from a 10 µm mesh low pressure filter; in addition cultured organisms can be added if required.
	Bacteria	Naturally occurring, or cultured species that may be added to the test water.	Ambient assemblage supplemented by the addition of standard test organisms.	Naturally occurring in the harbour outside the test facility (brackish and marine) and in Lake Arresø (fresh).
Intake organism diversity and density	Zooplankton, live organisms ≥ 50 µm in size	Organisms ≥50 µm in minimum dimension should be present in a total density of preferably 10^6 individuals but not less than 10^5 individuals per m^3, and should consist of at least 5 species from at least 3 different phyla/divisions.	Total concentration = minimum of 1×10^5 organisms/m^3.	Organisms ≥ 50 µm in minimum dimension are present in a total density above 10^5 live individuals per m^3 and consist of at least 5 species from at least 3 different phyla/divisions.
	Protists, live organisms C in size	Organisms ≥10 µm and less than 50 µm in minimum dimension should be present in a total density of preferably 10^4 individuals but not less than 10^3 individuals per ml, and should consist of at least 5 species	Organisms in the ≥10 µm and <50 µm size class must be present in minimum concentrations of 10^3 organisms/mL with at least 5 species across 3 phyla.	Organisms ≥10 µm and less than 50 µm in minimum visible dimension are present in a total density above 10^3 cells per mL, and consist of at least 5 species from at least 3 different phyla.

Parameter	Sub-category	IMO G8	ETV protocol	DHI
		from at least 3 different phyla/divisions.		
	Bacteria	Heterotrophic bacteria should be present in a density of at least 10^4 living bacteria per mL.	Organisms in the < 10 µm size class must be present in minimum concentrations of 10^3/mL as culturable aerobic heterotrophic bacteria.	Heterotrophic bacteria are typically present in a density of at least 10^4/mL as culturable aerobic heterotrophic bacteria.
Water quality of intake/source water	N/A	• Dissolved organic carbon (DOC): >5 mg/L; • Particulate organic carbon (POC): >5 mg/L; • Total suspended solids (TSS): >50 mg/L.	• Dissolved organic matter: min. 6 mg/L as DOC; • Particulate organic matter (POM): min. 4 mg/L as POC; • Mineral matter (MM): min. 20 mg/L; • TSS = POM + MM: min. 24 mg/L.	Dependent season and location, typical ambient values include: • DOC: 1-7 mg/L; • POC: 0-2 mg/L; • TSS: 1-20 mg/L. DOC, POC and TSS are typically adjusted to increase levels by using lignin sulphonate, maizena and kaolin, respectively.
Salinity of intake/source water	N/A	• Freshwater <3 PSU; • 10 PSU difference to brackish and marine	• Fresh <1 PSU; • Brackish 10-20 PSU; • Marine 28-36 PSU	• Fresh <1 PSU (Lake Arresø); • Brackish 15-28 PSU (harbour outside the test facility); • Marine 28-36 PSU (harbour water augmented by addition of brine)
Sample volume	Zooplankton, live organisms ≥ 50 µm in size	At least 20 L of intake water and 1 m^3 of treated water.	Minimum of 3 m^3 concentrated to 1,000 mL per sample.	Dependent on Test Plan: IMO G8. Inlet: At least 20 L concentrated to approx. 500 mL per sample. Treatment: Minimum 1 m^3, concentrated to approx. 500 mL per sample. USCG/ETV. Inlet: Minimum 1 m^3 concentrated to 500-1,000 mL Treatment: Minimum 3 m^3 concentrated to 500-1,000 mL.
	Protists, live organisms ≥10-<50 µm in size	At least 1 L of intake water and 10 L of treated water.	Minimum of 3 m^3 concentrated to 1,000 mL per sample.	Minimum 10 L per sample. 100-500 mL sub-sample concentrated to 20 mL on treated discharge
	Bacteria	At least 500 mL of intake water and 500 mL of treated water.	1,000 mL per sample.	At least 500 mL per sample*
Number of intake samples	Zooplankton, live organisms ≥ 50 µm in size	Minimum of 3 samples collected from the treatment track and 3 samples collected from the control track.	1 sample immediately prior to water entry to the control tank and 1 sample immediately before entry to the in-line BWMS, or (if control and challenge water are shown to be representative) one sample before the splitter.	IMO G8. 3 samples (start, middle, end). USCG/ETV. Minimum 1x1 m^3 continuous time integrated concentrated to 500-1,000 mL
	Protists, live organisms ≥10-<50 µm in size	Minimum of 3 samples collected from the treatment track and 3 samples collected from the control track.	1 sample immediately prior to water entry to the control tank and 1 sample immediately before entry to the in-line BWMS, or (if control and challenge water are shown to be representative) one sample before the splitter.	3 samples (start, middle, end)
	Bacteria	Minimum of 3 samples collected from the treatment track and 3 samples collected from the control track.	1 sample immediately prior to water entry to the control tank and 1 sample immediately before entry to the in-line BWMS, or (if control and challenge water are shown to be representative) one sample before the splitter.	3 samples (start, middle, end)
Number of discharge samples	Zooplankton, live organ-	Minimum of 3 samples collected from the treat-	1 sample from the discharge of the control tank, and 1 sample	Dependent on Test Plan: IMO: 3 continuous time inte-

Parameter	Sub-category	IMO G8	ETV protocol	DHI
	isms ≥ 50 µm in size	ment track and 3 samples collected from the control track.	from the discharge (following any treatments) of the treated water.	grated samples (min 3 × 1 m^3) collected from the control and treatment lines upon discharge. Representative sub-samples analysed. USCG/ETV: 1 continuous time integrated sample (min 3 m^3) collected from the control and treatment lines upon discharge. The equivalent of an entire cubic meter of discharge water should be examined for the presence of live animals.
	Protists, live organisms ≥10-<50 µm in size	Minimum of 3 samples collected from the treatment track and 3 samples collected from the control track.	1 sample from the discharge of the control tank, and 1 sample from the discharge (following any treatments) of the treated water.	3 × 10 L per sample (start, middle, end). 100-300 mL sub-sample concentrated to 25 mL
	Bacteria	Minimum of 3 samples collected from the treatment track and 3 samples collected from the control track.	1 sample from the discharge of the control tank, and 1 sample from the discharge (following any treatments) of the treated water.	3 × 500 mL per sample (start, middle, end). Representative sub-samples analysed.
Analytic end-points: Discharge density	Zooplankton, live organisms ≥ 50 µm in size	Less than 10 viable organisms per m3 greater than or equal to 50 µm in minimum dimension for treated water; more than 100 viable organisms per m^3 greater than or equal to 50 µm in minimum dimension for control water.	Less than 10 viable organisms per m3 greater than or equal to 50 µm in minimum dimension for treated water; more than 100 viable organisms per m^3 greater than or equal to 50 µm in minimum dimension for control water.	Less than 10 viable organisms per m^3 greater than or equal to 50 µm in minimum dimension for treated water; more than 100 viable organisms per m^3 greater than or equal to 50 µm in minimum dimension for control water.
	Protists, live organisms ≥10-<50 µm in size	Less than 10 viable organisms per mL less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension for treated water; more than 100 viable organisms per mL less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension for control water.	Less than 10 viable organisms per mL less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension for treated water; more than 100 viable organisms per mL less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension for control water.	Less than 10 viable organisms per mL less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension for treated water; more than 100 viable organisms per mL less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension for control water.
	Bacteria	Less than 1 colony forming unit (CFU) per 100 mL or less than 1 CFU/1 g (wet weight) zooplankton of toxicogenic *Vibrio cholerae* (O1 and O139), less than 250 CFU/100 mL of *E. coli*, and less than 100 CFU/100 mL of intestinal enterococci for treated water	Less than 1 CFU per 100 mL or less than 1 CFU/1 g (wet weight) zooplankton of toxicogenic *Vibrio cholerae* (O1 and O139), less than 250 CFU/100 mL of *E. coli*, and less than 100 CFU/100 mL of intestinal enterococci for treated water; Minimum concentration in control tank discharge is 5 x 10^2/mL.	Less than 1 CFU per 100 mL of toxicogenic *Vibrio cholerae* (O1 and O139), less than 250 CFU/100 mL of *E. coli*, and less than 100 CFU/100 mL of intestinal enterococci for treated water; More than 5 × 10^2/mL of heterotrophic bacteria in control tank discharge.
Water quality measurements	N/A	pH, temperature, salinity, dissolved oxygen, TSS, DOC, POC and turbidity (NTU) should be measured at the same time that the samples are collected.	Temperature, salinity, TSS, POM, DOM, mineral matter, dissolved oxygen, pH, chlorophyll a.	pH, temperature, salinity, dissolved oxygen, and turbidity (NTU) is continually measured by on-line monitoring on intake and discharge. TSS, DOC, POC, mineral matter and primary production (indirect measure of chlorophyll a) are measured at the same time that the samples are collected

Parameter	Sub-category	IMO G8	ETV protocol	DHI
Toxicity	N/A	Separate samples should be collected for toxicity testing of treated water, from the discharge, for systems that make use of active substances and also for those, which could reasonably be expected to result in changes to the chemical composition of the treated water such that adverse impacts to receiving waters might occur upon discharge. Tests should conducted in accordance with Resolution MEPC.126(53)) paragraphs 5.2.3 to 5.2.7 as amended.	Toxicity tests will be conducted for treatments involving biocides. Tests will be selected from a short list of U.S. EPA standard tests.	Whole effluent toxicity (WET) tests and residual by-product chemical analyses of control and treated discharge water is performed for systems involving active substances. Tests will be selected from a short list of OECD Guideline standard tests.
Biological sample analysis	N/A	Samples should be analysed as soon as possible after sampling, and analysed live within 6 hour or treated in such a way as to ensure that proper analysis can be performed. Widely accepted standard methods for the collection, handling, storage, and analysis of samples should be used.	Zooplankton enumeration: Concentrate using 35 µm mesh plankton nets; no preservation; subsample into well plate (20 1mL wells observed); observe with dissecting microscope and probe organisms to determine live/dead status; fix with Lugol's for total counts. Phytoplankton enumeration: No preservation; stain with FDA and CMFDA; load into a Sedgewick Rafter Counting Chamber and examine under epifluorescence using a FITC narrow pass filter cube. Bacteria: Plate on appropriate media; use a DNA colony blot hybridisation for *V. cholerae.*	Zooplankton enumeration: Concentrate using 35 µm mesh plankton nets; no preservation; subsample into Borogov counting chamber, observe with dissecting microscope and probe organisms to determine live/dead status; fix with Lugol's for taxonomic evaluation. Phytoplankton enumeration: 1) No preservation; stain with FDA and CMFDA; load into a Sedgewick Rafter Counting Chamber and examine under epifluorescence; 2) Phytoplankton re-growth assay by use of most probable number (MPN) and 3) Measurements of phytoplankton primary production. Bacteria: Enumeration of total viable heterotrophic bacteria, *E. coli*, and enterococci and preparation of colony blots for the detection of toxicogenic *V. cholerae.*
Flow rate	N/A	At least 200 m³/hr.	At least 200 m³/hr.	Up to 500 m³/hr. and not lower than 100 m³/hr.
Number and capacity of retention tanks	N/A	At least 1 control and 1 treatment tank with a minimum capacity of 200 m³ each.	At least 1 control and 1 treatment tank with a minimum capacity of 200 m³ each.	2 control and 4 treatment tanks each with a capacity of 250 m³.
Control/ treatment cycle sequence	N/A	Control and treatment cycles may be run simultaneously or sequentially.	Control and treatment cycles may be run simultaneously or sequentially.	Control and treatment cycles are typically run sequentially on uptake and on discharge
Retention time	N/A	At least 5 days.	Minimum of one day.	1 to 5 days, dependent on Test Plan.
Number of trials	N/A	At least 5 successes.	Minimum of five consecutive valid per salinity regime.	Minimum of 5 successful test cycles per salinity regime.
QA/QC	N/A	Quality Management Plan (QMP) addressing the quality control management structure and policies of the testing body, including subcontractors and outside laboratories; Quality Assurance Project Plan (QAPP) addressing the	A Test Plan with detailed test objectives, specific test procedures and quality control and assurance requirement shall be developed. A QAPP (annexed to the Test Plan), is to be compiled by the Testing Organisation, with input from the vendor. The QAPP will describe the proce-	Quality Management Plan (QMP) addressing the quality control management structure and policies of DHI; Quality Assurance Project Plan (QAPP) addressing the specifics of the DHI's biological efficacy performance evaluation of BWMS, its facilities, and other conditions affecting the

Parameter	Sub-category	IMO G8	ETV protocol	DHI
		specifics of the ballast treatment technology to be tested, the test facility, and other conditions affecting the actual design and implementation of the required experiments.	dures for conducting a test or study according to the verification protocol requirements for the application of a ballast water treatment system at a particular site. At a minimum, the QAPP shall detail test objectives, specific test procedures (including sample and data collection, sample handling, analysis and preservation), and quality control and assurance requirements (including measures of precision, accuracy, comparability, and representativeness).	actual design and implementation of the required experiments. A Test Plan describing the project specific details reflecting the Contract between the manufacturer and DHI.

5.1.2 Source water

Source water means the body of water, from which water is drawn for the land-based test. The IMO G8 guidelines /2/ and the ETV protocol /5/ describe three distinct water types that may be applied in the land-based test:

Fresh water (salinity <1 PSU)
Brackish water (salinity 10-20 PSU)
Marine water (salinity >32-36 PSU)

When fresh water is used, the source water will be collected in the Arresø Canal according to DHI SOP 30/1736 on collection of fresh water. Organism densities in the collected fresh water often exceed the minimum criteria for live organisms in test water with an order of magnitude allowing for dilution of the natural fresh water with potable water.

When brackish water is used, the source water will be collected immediately south of the pier adjacent to the test facility according to DHI SOP 30/1735; under normal conditions, the natural salinity of the source water will be 15-20 PSU.

When marine water is used, the source water will be collected immediately south of the pier adjacent to the test facility according to DHI SOP 30/1735, and brine will be added to achieve the required salinity.

5.1.3 Biological efficacy test cycles

5.1.3.1 BWMS treatment process

The biological efficacy (BE) test cycles will be conducted by use of the source tank (Tank D), control tank (Tank A1 or A2) and one retention tank per test cycle (Tank B1, B2, C1 or C2) (Figure 3.1).

The following steps are involved in the treatment of the test water in the BWMS (for definition and characterisation of test water, see Section 5.2):

1. A fraction of the test water (minimum 200 m³ and maximum 250 m³) contained in the source tank is transferred to the BWMS by pumping and treated here, after which it is transferred to one of the retention tanks (treated water).

2. Another fraction of the same test water (minimum 200 m³ and maximum 250 m³) is pumped directly into the control tank without passing the BWMS (control water). The control water serves as a control of BWMS performance.

3. Piping system and sample ports are cleaned (DHI SOP 30/1763).

For each BE test cycle, a minimum operational period of one (1) hour is required although this may be extended if the flow rate are lower than 200 m^3 per hour (as described in Section 5.4.5 in the ETV protocol /5/). The minimum operational period may decrease if the flow rate of the BWMS is higher than 200 m^3 per hour.

During ballasting, the flow, pressure, temperature, dissolved oxygen, pH, salinity, turbidity and water levels in the tanks are recorded automatically (DHI SOP 30/1764).

Samples are collected before and after first treatment by use of the relevant sample ports. Sampling is initiated when the flow rate has reached steady-state conditions, i.e. up to 5 minutes from start of operation (DHI SOPs 30/1738 and 30/1762). The samples are labelled according to procedures described in DHI SOP 30/1750.

5.1.3.2 Storage of treated and untreated test water

Following the treatment of the test water in the BWMS, the treated water is stored in the retention tank for at least five days ± 4 hours. The same storage time is applied for the control water.

5.1.3.3 Second treatment and discharge of test water

1. Treated water contained in the retention tank is pumped through the BWMS for second treatment, after which it is discharged into the harbour (treated discharge water)
2. Control water contained in the control tank is discharged into the harbour (control discharge water)
3. The retention tanks, piping system and sample ports are cleaned (DHI SOP 30/1763)

During de-ballasting, the flow, pressure, water temperature, dissolved oxygen, pH, salinity, turbidity and water levels in the tanks are recorded automatically (DHI SOP 30/1764).

Samples of the treated discharge water are collected by use of the sampling ports on the BWMS discharge line whereas samples of the control discharge water are collected by use of sampling ports on the test facility discharge line. Isokinetic sampling methodology with fixed sample volumes is applied according to principles described in MEPC.173(58) (G2) /9/.

5.1.4 Whole effluent toxicity testing

Whole effluent toxicity (WET) tests are conducted with treated discharge water and control discharge water in connection to BE test cycles. The WET testing includes chronic ecotoxicity tests covering three trophic levels (algae, crustaceans, fish). The WET tests are conducted in accordance with OECD Test Guidelines or ISO standards:

- Algae: OECD TG No. 201. Algal growth inhibition test (72 hours)
- Crustaceans: ISO/TC 147/SC5 ISO/CD 16778 (Draft 2012) "Water quality - Calanoid copepod early-life stage test with *Acartia tonsa* (5 days)
- Crustaceans: OECD TG No. 211. Daphnia magna reproduction test (21 days)
- Fish: OECD TG No. 212. Fish, embryo sac fry test (10 days)

WET tests are included as part of the performance evaluation of BWMS in accordance with the requirements in Resolution MEPC.174(58) (IMO G8 guidelines) /2/ and Resolution MEPC.169(57) (IMO G9 guidelines) /3/. The WET tests are supplemented with chemical analyses of disinfection by-products in the case that the IMO G9 guidelines are applied.

5.1.5 Operation and maintenance testing

The operation and maintenance (O&M) testing of the BWMS shall distribute testing of a minimum treated volume of 10,000 m^3 amongst the BE test cycles. The minimum total volume for the O&M test cycles is achieved by conducting five O&M test cycles, each with a minimum treated volume of 2,000 m^3.

5.2 Challenge conditions in BE verification testing

5.2.1 Test water – water quality characteristics

Test water (equivalent to the term challenge water /4; 5/) means the inlet water as contained in the source tank just prior to treatment. In land-based tests, source water may be adjusted to achieve the required challenge conditions.

The natural concentrations of dissolved organic carbon (DOC), particulate organic carbon (POC) and total suspended solids (TSS) in the source water are analysed, after which the test water will be prepared to meet the water quality parameters in Table 5.2.

Table 5.2 Minimum water quality characteristics according to the IMO G8 guidelines /2/ and the ETV protocol /5/ in parentheses

Parameter	Source water		
	Fresh (<1 PSU)	Brackish (10-20 PSU)	Marine (>32-36 PSU)
Dissolved organic carbon (DOC)	≥ 5 (6) mg/L	≥ 5 (6) mg/L	≥ 1 (6) mg/L
Particulate organic carbon (POC)	>5 mg/L	≥ 5 mg/L	≥ 1 (4) mg/L
Total suspended solid (TSS) Mineral materials (MM) ≥ 20 mg/L	>50 mg/L	≥ 50 mg/L	≥ 1 (24) mg/L

If necessary to obtain the stated water quality parameters, the concentrations of DOC, POC and mineral materials (MM) are increased by additions of lignin sulphonate (DOC), starch (POC) and kaolin clay (MM) as described in DHI SOP 30/1737.

5.2.2 Test water – biological organism conditions

The natural densities of live organisms in the source water are analysed with reference to size classes, after which the test water is prepared to meet the biological parameters in Table 5.3.

Table 5.3 Minimum densities of live organisms in the test water according to the IMO G8 guidelines /2/ and the ETV protocol /5/

Organism size class	Total concentration	Diversity
≥50 μm	10^5 organisms/m^3	5 species across 3 phyla
≥10 μm and <50 μm	10^3 organisms/mL	5 species across 3 phyla
<10 μm (only ETV protocol)	10^3/mL as culturable aerobic hetero-trophic bacteria	Not applicable

If necessary in order to obtain the stated minimum criteria, the densities of live organisms are increased by addition of harvested indigenous organisms and/or cultured species as described in DHI SOP 30/1734. Addition of harvested and/or cultured species is recorded in the data logging. Heterotrophic bacteria are typically present in the source water in densities exceeding the minimum criteria described in Table 5.3.

The minimum densities of live organisms in the control discharge water are presented in Table 5.4.

Table 5.4 Minimum densities of live organisms in the control discharge water according to the IMO G8 guidelines /2/ and the ETV protocol /5/

Organism size class	Total concentration
≥ 50 μm	100 organisms/m^3
≥10 μm and < 50 μm	100 organisms/mL
<10 μm (only ETV protocol)	5 × 10^2/mL as culturable aerobic heterotrophic bacteria

5.3 Sampling and analysis plan

A complete description of the sampling and analyses is provided in the Test Plan.

5.4 Analytical procedures

The specific analyses applied in the land-based test and the associated DHI SOPs are described in Chapter 7.

6 Performance evaluation in shipboard test

6.1 Experimental design

6.1.1 Source water

The source water used for the testing shall be representative of harbour or coastal waters. The natural densities of live organisms in the source water are analysed with reference to size classes. The densities of live organisms in the size classes ≥50 µm and ≥10 µm to <50 µm (Table 6.1) must exceed 10 times the maximum permitted values in the IMO D-2 standard /1/, which is similar to the ballast water discharge standard /4/.

Table 6.1 Minimum densities of live organisms in the source water in shipboard test according to the IMO G8 guidelines /2/ and the U.S. Coast Guard Standards /4/

Organism size class	Total concentration	Diversity
≥50 µm	100 organisms/m³	No requirement
≥10 µm and <50 µm	100 organisms/mL	No requirement

6.1.2 Biological efficacy test cycles

The organisation of the BE test cycles and the associated trial periods and locations are described in the Test Plan.

6.2 Sampling and analysis plan

A complete description of the sampling and analyses is provided in the Test Plan.

6.3 Analytical procedures

The specific analyses applied in the shipboard test and the associated DHI SOPs are described in Chapter 7.

7 Data management, analyses and reporting

7.1 Data management

During the land-based or shipboard test information is recorded in relation to

- Personnel participating in cleaning and maintenance at the test facility and collection of samples

- Operational procedures and monitoring
- Sampling and analysis

The data are recorded in accordance with the data-logging procedures described in the respective SOPs. A complete overview of the DHI SOPs used for BWMS performance evaluation in land-based or shipboard tests is presented in Appendix B.

An Access-based database and the procedures described in DHI SOP 30/1750 are used for storage of data generated from the BE test cycles and for marking completed QC of individual data. This data-level QC is made with reference to data quality indicators (DQI) described in the SOPs.

All generated data and all other records and information relevant to the quality and integrity of the performance evaluation, including a copy of the database file(s) and original raw data, is retained in the archives of DHI for a period of five years after issue of the final report.

7.2 Analyses

7.2.1 Organism size class ≥50 µm

Compliance with the pass criterion in Chapter 9 will be verified by use of the direct count of organisms ≥50 µm in minimum dimension.

The concentrations of live organisms ≥50 µm in minimum dimension are determined by use of a stereo microscope and a counting chamber according to DHI SOP 30/1700. Viable organisms are enumerated by use of standard movement and response stimuli technique. The viable organisms are characterized according to broad taxonomic groups such as crustaceans (e.g. copepods), molluscs, rotifers, worms, etc.

7.2.2 Organism size class ≥10 µm and <50 µm

Compliance with the pass criterion in Chapter 9 will be verified by use of a combination of methods which shall be stated in the Test Plan.

Verification of compliance with the pass criterion for the size class ≥10 and <50 µm in minimum dimension is not straight-forward, because conventional vital staining is not directly applicable for determination of live organisms of all ballast water management technologies. E.g., ultra violet (UV) radiation may kill the organisms, but the esterase activity causing the response of the vital stains chloromethylfluorescein diacetate (CMFDA) and fluorescein diacetate (FDA) is not immediately inactivated, and this will result in "false positive" counts. Therefore, a combination of methods is used to determine the concentrations of live organisms in the size class ≥10 and <50 µm.

Examples:

For BWMS using e.g. active substance(s), compliance with the pass criterion in Chapter 9 may be verified by use of the direct count of CMFDA/FDA labelled organisms ≥10 and <50 µm in minimum dimension by use of an epifluorescence microscope.

For BWMS using filtration and UV radiation, compliance with the pass criterion in Chapter 9 may be verified by use of the total of viable organisms determined by measuring algal re-growth using a most probable number (MPN) assay and enumeration of viable moving organisms ≥10 and <50 µm in minimum dimension that are not encompassed by the algal re-growth assay (i.e. CMFDA/FDA labelled organisms without chlorophyll).

To support the determination of concentrations of organisms in the ≥10 µm and <50 µm size class, a combination of the following analytical methods may be applied. The selection of methods shall be stated in the Test Plan:

Inverted microscopy (DHI SOP 30/1701). The concentrations of organisms and the presence of taxonomic groups in the inlet water are determined by inverted microscopy. Inverted microscopy is also be used to determine the taxonomic groups of algae that are able to grow under the conditions applied in the algal re-growth assay.

Vital staining with CMFDA and FDA (DHI SOP 30/1701). CMFDA and FDA are added to a subsample and, after incubation, the subsample is examined by use of a microscope under epifluorescence. Organisms labelled by either CMFDA or FDA are considered viable as described in DHI SOP 30/1701.

Algal re-growth assay (DHI SOP 30/1704). Viable algae are quantified by measuring re-growth in a most probable number (MPN) assay. A dilution series is prepared by adding aliquots of subsample to test tubes with liquid medium. The test tubes are incubated for 14 days at ambient temperature. The concentrations of viable algae in the inlet water, control discharge water and treated discharge water are determined by measuring of the fluorescence in the test tubes before and after incubation according to DHI SOP 30/1704. The algal re-growth assay is considered to provide the most reliable results to be used for a performance evaluation of BWMS applying UV treatment as the method is directly linked to algal growth and, thus, indicative of the ability of the organisms to establish and reproduce in the environment. The algal re-growth assay includes planktonic algae without reference to size, and, thus, it is not limited to the ≥10 µm and <50 µm size class.

Algal primary production (DHI SOP 30/1702). The algal primary production is determined by measuring the ^{14}C fixed by photosynthesis. For each field replicate, $NaH^{14}CO_3$ (2 µCi) is added to two subsamples. These subsamples are incubated for approx. 75 min under light from a light panel at ambient temperature. After incubation, the samples are filtered onto Whatman GF/D filters. The filters are transferred to glass vials, and acid is added directly to the filters to release $^{14}CO_2$. The ^{14}C activity remaining in the algae on the filters after acidification is quantified by liquid scintillation counting according to DHI SOP 30/1702. The algal primary production assay includes planktonic algae without reference to size, and, thus, it is not limited to the ≥10 µm and <50 µm size class.

7.2.3 Organism size class <10 µm (bacteria)

The concentrations of heterotrophic aerobic bacteria are determined according to DHI SOP 30/1706 (ISO 6222). *E. coli* and enterococci are analysed according to DHI SOP 30/1708. *Vibrio cholerae* is analysed according to the method described in DHI SOP 30/1707 (ISO 21872).

7.2.4 Physical/chemical analyses

The physical/chemical analyses conducted according to DHI SOPs 30/1764 and 30/1766 include:

Land-based test:

- pH
- Turbidity
- Dissolved oxygen
- Ballast system pressure
- Ballast system flow rates
- UV-transmittance at 254 nm, 1 cm
- Water volume in retention tanks

Land-based and shipboard test:

- Temperature
- Salinity
- Dissolved organic carbon (DOC)
- Particulate organic carbon (POC)
- Total suspended solids (TSS)

8 Validity criteria

8.1 Land-based test validity criteria

A valid BE test cycle implies that the average concentrations of viable organisms in the control discharge water exceed the minimum densities in Table 5.4:

- 100 organisms per m^3 for the size class ≥50 µm (IMO G8 guidelines, Annex, Part 2, Section 2.3.36 /2/; ETV protocol, Section 5.4.7.3 /5/)
- 100 organisms per mL for the size class ≥10 µm and <50 µm (IMO G8 guidelines, Annex, Part 2, Section 2.3.36 /2/; ETV protocol, Section 5.4.7.3 /5/)
- 500 per mL for the size class <10 µm (ETV protocol, Section 5.4.7.3 /5/)

The test report shall verify that the criteria for a valid BE test were met, or deviation from the criteria shall be scientifically justified (e.g., grazing by high numbers of zooplankton may imply that the required density for the size class ≥10 µm and <50 µm cannot be accomplished in the control water at discharge).

Although the water quality and the biological challenge conditions are not defined as validity criteria in the IMO G8 guidelines /2/ and the ETV protocol /5/, the test water should meet the minimum water quality characteristics in Table 5.2 and the minimum densities of live organisms and diversity ranges in Table 5.3.

The minimum water quality characteristics and the minimum densities of live organisms in the test water shall ensure that relevant challenge conditions are obtained in the BE test. The challenge conditions in Tables 5.2 and 5.3 can normally be met by the preparation of the test water, but natural variation in the composition of the source water may occasionally result in concentrations of DOC, POC and TSS or densities of live organisms that are slightly lower than the minimum values. A deviation of less that 10% below the minimum values in Tables 5.2 and 5.3 is considered relevant challenge conditions that do not impair the validity of the BE test. Any deviation in the average concentrations below 90% of the minimum values shall be clearly described and discussed in test report.

8.2 Shipboard test validity criteria

A valid BE test cycle implies that:

- The average concentrations of viable organisms in the source water are at least 10 times higher than the maximum permitted values in the IMO D-2 standard (IMO G8 guidelines, Annex, Part 2, Section 2.2.2.5 /2/), excepted from the requirements to bacteria, which is similar to the ballast water discharge standard (U.S. Coast Guard standards, §162.060-28 /4/). Minimum densities of live organisms are provided in Table 6.1
- The average concentrations of viable organisms in the control discharge water exceed the maximum permitted values in the IMO D-2 standard (IMO G8 guidelines, Annex, Part 2, Section 2.2.2.5 /2/) except for the requirements to bacteria, which is similar to the ballast water discharge standard (U.S. Coast Guard standards, §162.060-28 /4/).

9 Pass criteria

A valid BE test cycle, as part of either a land-based or a shipboard test, is regarded successful if it meets the performance standard for treated ballast water at discharge (IMO Regulation D-2 /1/ and United States Coast Guard /4/ (§151.2030)):

1. The average density of organisms larger than or equal to 50 µm in minimum diameter in the replicate samples shall be less than 10 viable organisms per m^3 at discharge

2. The average density of organisms smaller than 50 µm and larger than or equal to 10 µm in minimum diameter in the replicate samples shall be less than 10 viable organisms per mL at discharge

3. The average density of *Vibrio cholerae* (serotypes 01 and 0139) shall be less than 1 colony forming unit (CFU) per 100 mL at discharge

4. The average density of *E. coli* in the replicate samples shall be less than 250 CFU per 100 mL at discharge

5. The average density of intestinal enterococci in the replicate samples shall be less than 100 CFU per 100 mL at discharge

10 Quality assurance and control

10.1 Quality assurance

The project is conducted in accordance with the principles of ISO 9001 by using the DHI Business Management System and the procedures in the QMP /6/.

The DHI quality manager is responsible for assigning a trained internal auditor from DHI's Quality Assurance Unit to each project in accordance with the procedures for internal audit in the DHI Business Management System (Section on Quality). The internal auditor shall not be involved in solving the specific project or in any project deliverables.

The DHI Business Management System (Section on Quality; Internal Audit) describes procedures for audit and evaluation and the process of periodic internal auditing of projects and activities including audit responsibilities and planning, auditor training and competences and audit reporting.

The DHI Business Management System (Section on Quality; Correction and Prevention) describes procedures for corrective actions, i.e. how deviations identified during operation and auditing are corrected and how future occurrence of the same deviations is prevented (preventive actions).

10.2 Quality control

Quality control of individual data, or data-level QC, of BWMS operational conditions, sampling and analyses is conducted with reference to data quality indicators (DQI) in the DHI SOPs by staff appointed for this task (see Section 2.2). The DQI include accuracy, precision, bias, representativeness, completeness, comparability, and sensitivity. The DQI and how they are monitored and evaluated are described in the relevant DHI SOPs.

Records of completed data-level QC are stored in an Access-based database (DHI SOP 30/1750), and a copy of the relevant database file(s) will be retained in the DHI archives for a period of five years after issue of the final report.

Quality control of the QAPP, DHI SOPs and all project proposals, deliverables and reports is conducted by management (see Section 2.2).

11 References

/1/ IMO. International Convention for the Control and Management of Ships' Ballast Water and Sediments. London. International Maritime Organization, 2004.

/2/ MEPC. Guidelines for Approval of Ballast Water Management Systems (G8). Resolution MEPC.174(58). Adopted 10th October 2008.

/3/ MEPC. Procedure for Approval of Ballast Water Management Systems that Make Use of Active Substances (G9). Resolution MEPC.169(57) Adopted 4th April 2008.

/4/ U.S. Coast Guard. Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters. Federal Register, Vol. 77, No. 57, March 23, 2012.

/5/ U.S. Environmental Protection Agency, Environmental Technology Verification Program. Generic Protocol for the Verification of Ballast Water Treatment Technology. EPA/600/R-10/146, September 2010.

/6/ Quality management plan. Performance Evaluation of Ballast Water Management Systems. DHI Denmark. Version 3.1. May 2012.

/7/ EN ISO/IEC 17025. General requirements for the competence of testing and calibration laboratories /ISO/IEC 17025, 2005.

/8/ OECD Principles of Good Laboratory Practice (as revised in 1997). Organisation for Economic Co-operation and Development (OECD), Paris. ENV/MC/CHEM (98)17.

/9/ Resolution MEPC.173(58). Adopted on 10 October 2008. Guidelines for approval of ballast water sampling (G2).

APPENDIX A

Certificate of compliance, ISO 9001 certificate, accreditation and GLP authorisation

COPY

Certificate no: **DS/I093222-A**
Page 1 of 1

Lloyd's Register

Certificate of Compliance

Office: **Lloyd's Register EMEA**
Copenhagen Design Support Centre, Statutory Section
Strandvejen 104A, 2nd floor
DK-2900 Hellerup
Denmark

Date: **09 May 2012**

This certificate is issued to **DHI Ballast Water Centre, Denmark**

DHI Ballast Water Centre, Denmark

The Document(s) listed in paragraph 1 of the appendix have been examined for compliance with:

- Resolution MEPC.174(58), Annex part 2

and are found to comply from quality assurance and quality control aspects subject to the following:

1.1. It is required to maintain full and accurate log files in order to demonstrate correct quality measures

1.2. The Quality Assurance Project Plan is a project specific document and should as such be subject to review and commenting prior to each project start-up.

1.3. This design appraisal document is to be kept together with quality management plan.

1.4. Subject certificate is valid until 15 June 2015.

1. The documents listed below have been examined

Drawing No.	Rev.	Title	Status	Date
Date: 07 Sep 2011	**2.3**	**Quality Management Plan**	**B**	**09 May 2012**

2. The documents listed below have been considered together with the submitted documents in the appraisal

Drawing No.	Rev.	Title
11810704	**02**	**Quality Assurance Project Plan**

Appraisal Status Key

B Examined and found to comply with §2.2, Part 2 of the annex of IMO Resolution MEPC 174 (58)

Martin Schabert
Statutory Department
Copenhagen Design Support Centre
Surveyor to Lloyd's Register EMEA

LLOYD'S REGISTER EMEA
Lloyd's Register
M. Schabert
COPENHAGEN DESIGN SUPPORT CENTRE

A member of the Lloyd's Register Group

Form 1124 (2005.02)

DHI

DNV BUSINESS ASSURANCE

MANAGEMENT SYSTEM CERTIFICATE

Certificate No. 109333-2012-AQ-DEN-DANAK

This is to certify that

DHI Group

has been found to conform to the management system standard:

DS/EN ISO 9001:2008

This certificate is valid for the following product or service ranges:

Consulting, software, research & development and laboratory testing, analysis & products within the area of water, environment & health

Locations included in the certification will appear in the appendix.

Place and date:
Hellerup, 2012-03-23

DET NORSKE VERITAS,
BUSINESS ASSURANCE, DANMARK A/S

This certificate is valid until:
2015-01-10

DANAK
SYSTEM Reg nr. 5001

The audit has been performed under the supervision of:

Jan Carsten Schmidt
Lead Auditor

Jens Peter Høiseth
Managing Director

Lack of fulfilment of conditions as set out in the Certification Agreement may render this certificate invalid.

DNV BUSINESS ASSURANCE

APPENDIX TO CERTIFICATE

This appendix refers to certificate no. 109333-2012-AQ-DEN-DANAK

DHI Group

Locations included in the certification are as follows:

Site Address	Scope:
Agern Allé 5 2970 Hørsholm, Denmark	Consulting, MIKE© by DHI Software Development, Sales & Support, Solutions Software Development, Research, Development & Innovation and Laboratory Analysis, Testing & Products
INCUBA Science Park, Gustav Wieds Vej 10 8000 Århus, Denmark	Consulting, Solutions Software Development and Research, Development & Innovation
Drakegatan 6, 412 50 Göteborg, Sweden	Consulting, MIKE© by DHI Software Sales & Support
Kyrkogatan 3, 222 22 Lund, Sweden	Consulting, MIKE© by DHI Software Sales & Support
Svartmangatan 18, 111 29 Stockholm, Sweden	Consulting, MIKE© by DHI Software Sales & Support
Honnörsgatan 16, Box 3287, 350 53 Växjö, Sweden	Consulting, MIKE© by DHI Software Sales & Support

Place and date:

Hellerup, 2012-03-23

DET NORSKE VERITAS,
BUSINESS ASSURANCE, DANMARK A/S

This certificate is valid until:

2015-01-10

DANAK
SYSTEM Reg nr. 5001

The audit has been performed under the supervision of:

Jan Carsten Schmidt
Lead Auditor

Jens Peter Høiseth
Managing Director

Lack of fulfilment of conditions as set out in the Certification Agreement may render this certificate invalid.

Accreditation to testing

COPY

DANAK

Company: **DHI**

Agern Allé 5
DK-2970 Hørsholm

Registration number: **26**

Valid: **24-10-2012 to 31-07-2015**

Scope:

Testing

Product

- **Biological items**
- **Chemicals and chemical products**
- **Construction products**
- **Environmental samples**

Test Type

- **Biological and biochemical testing**
- **Chemical testing**
- **Microbiological testing**
- **Ionising radiation and radiochemistry**
- **Sampling**

Testing is performed according to the current list of test methods approved by DANAK.

The company complies with the criteria in EN ISO/IEC 17025:2005 – General requirements for the competence of testing and calibration laboratories and demonstrates technical competence for the defined scope and the operation of a quality management system (refer joint ISO-ILAC-IAF Communiqué dated January 2009, www.danak.dk).

Issued the 24 October 2012

f. Jesper Høy / **Kirsten Jebjerg Andersen**

In case of any disputes, the Document in Danish language shall have priority

Den Danske Akkrediterings- og Metrologifond

COPY DANAK

GOOD LABORATORY PRACTICE

STATEMENT OF COMPLIANCE

Laboratory inspection and study audits for compliance with the OECD Principles for Good Laboratory Practice were carried out at

Laboratory: DHI

on

Dates: 21st and 22nd October 2011

The laboratory inspection and study audits have been carried out in accordance with the regulation settled in Order No. 906 of 14th September 2009 from the Danish Ministry of Environment. The laboratory has been monitored for GLP Compliance within the following scope:

Type of products:

- *Industrial chemicals*
- *Pesticides*
- *Biocides*

Type of tests:

- *Environmental toxicity studies on aquatic and terrestrial organisms.*
- *Studies of behaviour in water, soil and air, bioaccumulation*

The laboratory was found to be operating in compliance with the OECD Principles of Good Laboratory Practice.

Date: 08 August 2012

Jesper Høy
Managing director, DANAK

Kirsten Jebjerg Andersen
GLP inspector, DANAK

Den Danske Akkrediterings- og Metrologifond

APPENDIX B

Overview of DHI SOPs

SUBJECT/SUBSUBJECT	DHI SOP NO.
ANALYTICAL METHOD DETERMINATION OF VIABLE ORGANISMS ≥50 μm	30/1700
ANALYTICAL METHOD DETERMINATION OF VIABLE ORGANISMS ≥10 μm AND < 50 μm	30/1701
ANALYTICAL METHOD DETERMINATION OF PRIMARY PRODUCTION OF MICROALGAE	30/1702
ANALYTICAL METHOD DETERMINATION OF VIABLE ALGAE BY RE-GROWTH ASSAY	30/1704
MICROBIOLOGICAL TESTS DETERMINATION OF TOTAL NUMBER OF BACTERIA BY EPIFLUORESCENCE MICROSCOPY	30/1705
MICROBIOLOGICAL TESTS DETERMINATION OF HETEROTROPHIC PLATE COUNT	30/1706
MICROBIOLOGICAL TESTS DETERMINATION OF *VIBRIO CHOLERAE* IN WATER	30/1707
MICROBIOLOGICAL TESTS DETERMINATION OF TOTAL COLIFORM, E.COLI AND ENTEROCOCCI	30/1708
MEASUREMENT METHOD TRO MEASUREMENT IN WATER	30/1732
HARVESTING, CULTURING AND ADDITION OF ORGANISMS	30/1734
COLLECTION OF SEAWATER	30/1735
COLLECTION OF FRESH WATER	30/1736
CRITERIA FOR TEST WATER ADDITION OF DOC, POC, MM AND BRINE	30/1737
SAMPLING PREPARATION, SUBSAMPLING AND TRANSPORTATION OF SAMPLES	30/1738
DATABASE SAMPLES, LABELS AND DATA SHEETS	30/1750
OPERATION OF THE DHI MTEF	30/1762
CLEANING RETENTION TANKS; PIPINGS AND OTHER EQUIPMENT AT TEST SITE	30/1763
MEASUREMENT METHOD ON-LINE MONITORING OF PRESSURE, TEMPERATURE, FLOW RATES AND QUALITY PARAMETERS AT TEST SITE	30/1764
MEASUREMENT METHOD FLUORESCENCE	30/1765
MEASUREMENT METHOD TURBIDITY	30/1766
DHI MTEF HEALTH AND SAFETY	30/1767
MEASUREMENT METHOD DETERMINATION OF TSS	30/1768
MEASUREMENT METHOD DETERMINATION OF DOC AND POC	30/1769
MEASUREMENT METHOD DETERMINATION OF TRANSMITTANCE	30/1770

APPENDIX B

Data logging format for the shipboard testing with RayClean

Table B.1.1 Test cycle data logging; treated water

Subject	Data
BWMS	
Manufacturer specified parameters (e.g. number of treatment reactors/units, filter model, filter mesh size, etc.)*	
Salinity (PSU)	
Ballast tank No.	
Test cycle No.	
Location for ballast (port name and terminal or coordinates)	
DHI personnel on-board; ballast	
Date and time ballast start	
Date and time ballast stop	
Treated volume during ballast*	m^3
Flow rate during ballast (average)	m^3/h
Power consumption during ballast*	
UV intensity during ballast*	
Location for de-ballast (port name and terminal or coordinates)	
DHI personnel on-board; de-ballast	
Date and time de-ballast start	
Date and time de-ballast stop	
Treated volume during de-ballast*	
Flow rate during de-ballast (average)	
Power consumption during ballast*	
UV intensity*	
Weather conditions during test*	
General comments/operational issues	

* Information on manufacturer-specified parameters, coordinates (if applicable), treated volumes, power consumption, UV intensity data provided by the manufacturer (readings or datalog from manufacturer equipment). Weather conditions during voyage under a BE test cycle recorded by the vessel crew in case DHI personnel is not able to stay on the vessel for the duration of the test due to limitations in life saving appliances.

Table B.1.2 Test cycle data logging; control water

Subject	Data
Salinity (PSU)	
Ballast tank No.	
Location for ballast (port name and terminal or coordinates)	
Date and time ballast start	
Date and time ballast stop	
Volume during ballast	m^3
Flow rate during ballast (average)	m^3/h
Location for de-ballast (port name and terminal or coordinates)	
Date and time de-ballast start	
Date and time de-ballast stop	
Volume during discharge	
Flow rate during discharge (average)	
General comments/operational issues	

APPENDIX C

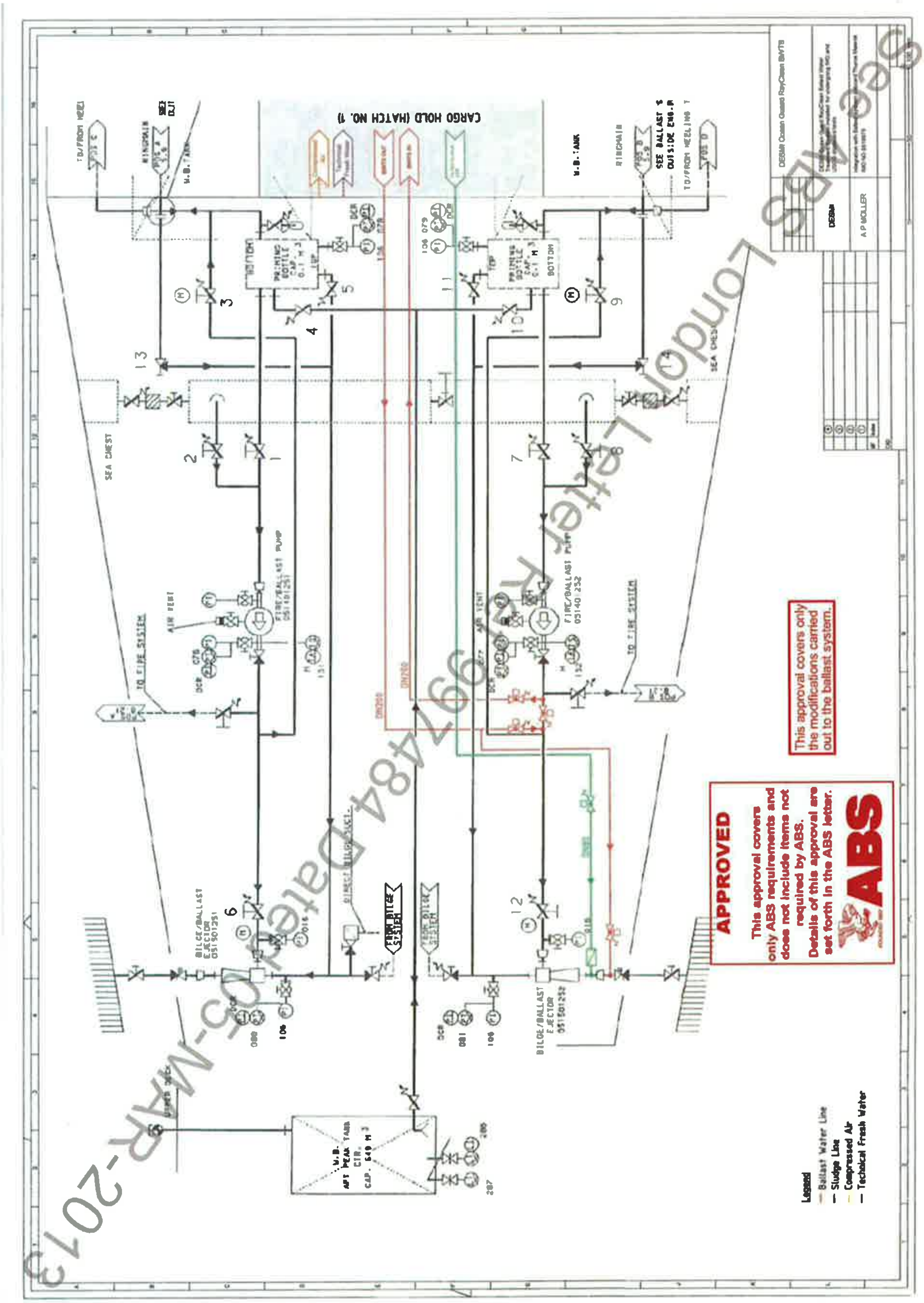
Description of ship and technology
as provided by the manufacturer

Thurø Mærsk is a container vessel.

Thurø Mærsk has been used for shipboard testing of the Mahle BWTS as well as the DESMI Ocean Guard OxyClean. Thurø Mærsk has a 300 m^3/h ballast pump, which also is a fire fighting pump. The test system is placed in a 40' container with steel piping from the ballast system to the container. The system can be operated from the container as well as via a laptop placed at the deck office.

Ballast tanks 3 A + B and 4 A + B can be used for test purposes. It is the intention to make the 5 test runs at the Iberian Peninsula. First test runs on 21 May 2013 in Lisbon, Portugal, with de-ballast on 23 May 2013 in Leixous (Porto), Portugal.

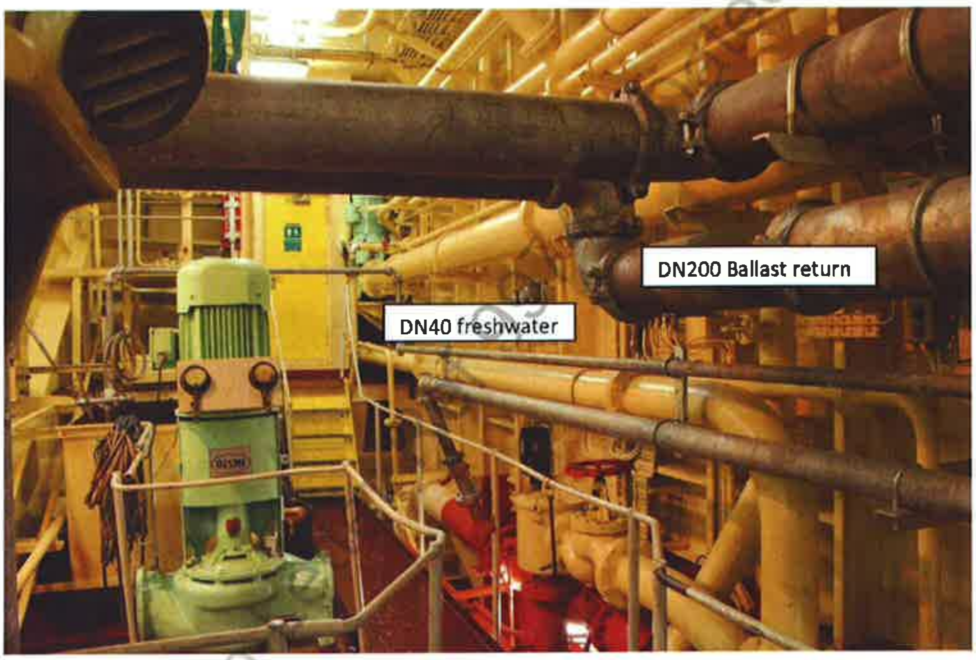
Information about Thurø Mærsk: http://www.shipspotting.com/gallery/photo.php?lid=343767


CARGO HOLD (HATCH NO. 1)
SEA CHEST
FIRE/BALLAST PUMP
BILGE/BALLAST EJECTOR
PRIMING BOTTLE
TO FIRE SYSTEM
FROM BILGE SYSTEM
AIR VENT
W.B. TANK
APPROVED
This approval covers only ABS requirements and does not include items not required by ABS. Details of this approval are set forth in the ABS letter.
ABS
This approval covers only the modifications carried out to the ballast system.
Legend
Ballast Water Line
Sludge Line
Compressed Air
Technical Fresh Water

Thuroe Mærsk - Servyman – DESMI Ocean Guard

Ejector by pass solution:

The assignment in the engine room relates to two different piping system: the return from the cargo hold/ the ballast water treatment system (DN200) and the technical freshwater going to the cargo hold / the ballast water treatment system (DN40).



DN40: The technical freshwater pipe will be change in the following way:

Section 1 will be change to a new approx. 60 mm longer pipe.

Section 2 will remain the same

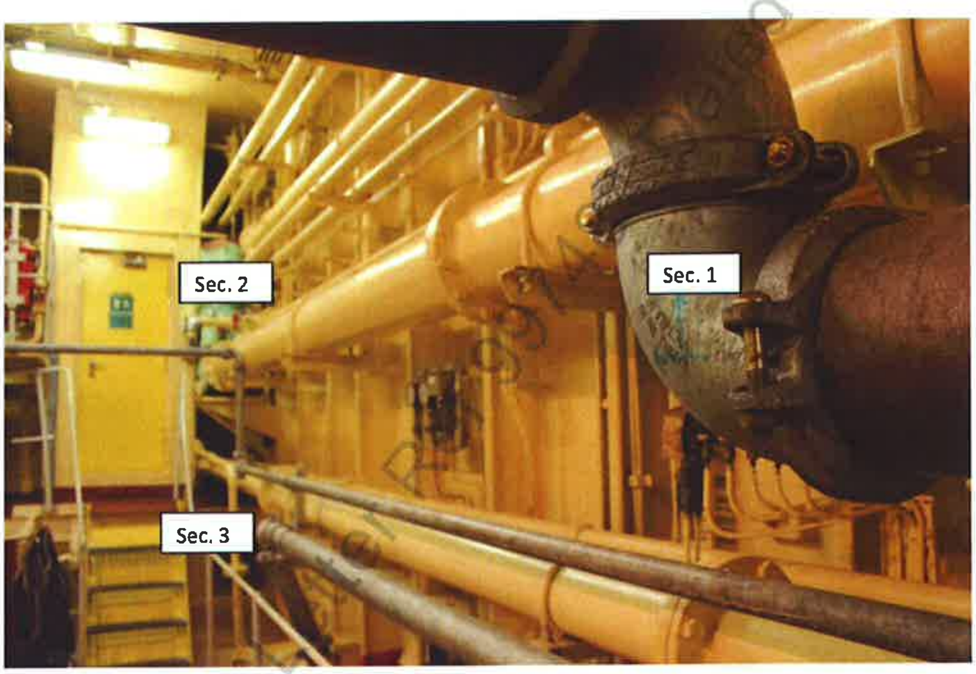
Section 3 will be cut, right before the support and refitted with 2 x 90 degree bends.

DN200: The ballast water return will be changed in the following way:

Section 1: the 90 degree bend will be changed to a T piece

Section 2: the 90 degree bend will be used to direct the water to the pipe section between the ejector and ballast water overboard valve.

Section 3: a DN 200 valve is installed approx. 300 mm above the connection point. The valve will be installed same way as the valves already installed (short pipe length – victaulic coupling – valve – victaulic coupling – pipe)



Operation Maintenance and Safety Manual

RayClean
DESMI Ocean Guard

BWMS TEST SYSTEM - LANDBASED TEST

DHI – HUNDESTED - DENMARK

1 Revision history

Revision	Description	Author	Date	Approved	Date
0	1st Issue	JFR	20-03-2013	COI	30-03-2013
1	Control Curve changed and various chapters extended and corrected.	JFR	23-04-2013	RFO	23-04-2013

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2 Manufacturer's information

2.1 DESMI Ocean Guard Contact Points

COMPANY:	PERSONAL:	FOR QUESTIONS RELATED TO
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	Technical Manager Christian Ingvorsen: Mobile: +45 20160026 Mail: coi@desmiocenaguard.com	The installation and integration of the system. Test procedures - setup Spare parts.
	Project Manager Mark Kalhøj: Mobile: +45 25466301 Mail: mka@desmioceanguard.com	Physical design and biological performance of the system. Spare parts
	Automation Manager Michael Claville: Mobile: +45 22507597 Mail: mcl@desmioceanguard.com	Operating Panel – Human Machine Interface Layout. Electrical and CRS(Control, Regulation and Supervision)
	Compliance Manager Jørgen Frahm Mobile: +45 91373449 Mail: jfr@desmioceanguard.com	Layout and content in Operation Maintenance Safety Manual Compliance with requirements Documentation in general

2.2 General

These operating instructions are designed to make it easier to get to know the DESMI Ocean Guard – Ballast water treatment system and a make proper use of it. The operating instructions contain all important instructions on how to operate the system. Read the technical and operating instructions carefully and attentively. Supplement the operating and technical instructions with any instructions required due to existing national and international regulations for the prevention of accidents and environmental protection. Make sure that the operating instructions always are available when using the system. The operating instructions must be read and applied by every person involved.

2.3 Liability

The "General Terms and Conditions" of DESMI Ocean Guard shall not recognize any warranty or liability claims for personal and material damages if they can be attributed to one or more of the following causes: Improper use of the system, failure to comply with the information and instructions in the technical or operating instructions, arbitrary constructional modifications to the system, insufficient monitoring of parts which are subject to wear and tear, maintenance/repair work performed improperly or too late, disasters caused by external influences or an act of God. All the information in this manual is provided to the best of our knowledge based on our prior experience. We reserve the right to make technical changes as part of further technical development. The text and graphic illustrations do not necessarily correspond exactly to the actual system. Reference to any deviations is made in the respective place if required for comprehension. The graphic illustrations are not true to scale.

2.4 Copyright

This manual is a certified document as per the terms of the law against unfair competition. The copyright of the document is held by DESMI Ocean Guard A/S. These operating instructions are for the user of the system and the user's staff. The document contains text and drawings which, without the express permission of the manufacturer must not be reproduced, distributed or otherwise made available to others, either in full or in part.
Failure to comply will require compensation.

2.5 Terms and definitions

Terms and definitions follow the terminology provided in MEPC guidance documents.

3 Principles of ballast water management system (BWMS) operation

3.1 Description of the BWMS, methods and type(s) of technologies

3.1.1 Description of the BWMS

The concept of the DESMI Ocean Guard – RayClean™ system is a combination of filtration and low pressure UV irradiation.

Essential components in the system:

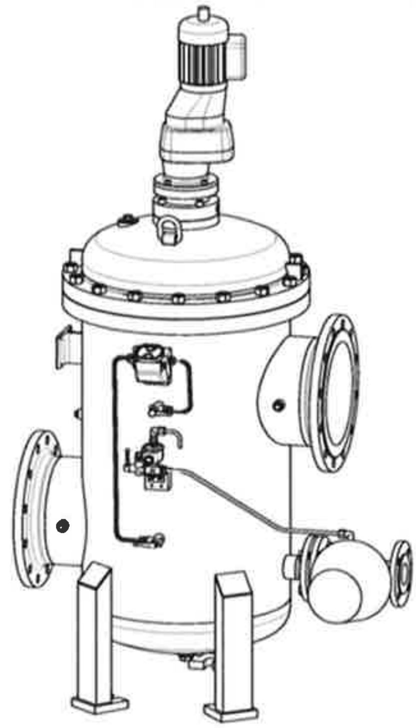
- Filter: 30 μm pressurized filter
- UV-irradiation: 325 W low pressure UV lamp (100 W UVC output)

The RayClean-300 system that will be tested has a 300 m^3/h Treatment Rated Capacity. Scalability is achieved by adding more 300 m^3/h UV units, meaning that systems from 1 – 300 m^3/h needs one UV unit, systems from 301 – 600 m^3/h needs two UV units and so on.

3.1.2 DESMI Ocean Guard RayCleanTM Filter

Prior to the actual RayClean™ system there will normally be placed a mechanical filter at the sea chest. The purpose of the filter is to remove larger organisms and general debris.

The filter system included in the RayClean™ system is a standard pressurized filter with screens of 30 micron, which is installed after the ballast water pump.



The filter removes particles so that the efficiency of the succeeding disinfection step is secured. The filter is automatically cleaned and flushed during operation. The concept is that when the pressure difference is passing a set value the filter is cleaning itself. If the amount of particles in the water is so low that the pressure drop over the filter is extremely low, a timer will clean the filter automatically when a certain time without cleaning operation has been reached.

3.1.3 DESMI Ocean Guard RayCleanTM UV-unit

The UV system consists of one UV-unit for each 300 m3/h treatment rated capacity. Each UV-unit contains sixty 325W UV-lamps, which are based on low-pressure UV-lamp technology. The UV lamps are prepared for the marine environment by having completely sealed steel end caps to avoid corrosive aerosols to reach electric circuits. EX protection will also enable the installation in hazardous areas (Ex classification not yet received).

These lamps have an efficiency of approx. 30% in converting energy to useful UVC light. The other dominant lamp types on the market - medium pressure lamps - have a total efficiency of approx. 15% of the consumed energy. The low-pressure UV lamps emit light at 254 nm which is a photolytic inactivating wavelength. UV-lamps are installed in quartz-tubes which allow the 254 nm rays to pass for photolytic inactivation of organisms in the ballast water.

The system is delivered with a visual lamps failure alarm for each lamp, ensuring continued operation even if a lamp needs to be excluded due to failure. Further each lamp has an elapsed time meter making traceability of lamp operation simple. Cabinet material will be seawater resistant. UV-unit temperature is constantly monitored to ensure shot down in case of water flow failure or air present in the reactor. The temperature surveillance is the last safety barrier, and will disable the ballast system until serviced.

Standard low pressure UV lamps are doped so that they only emit light at 254 nm which is close to the optimal germicidal wave length. The applied UV-dose will be regulated by obtaining the intensity from a specific distance with a UV sensor and lamp ballast electronics will regulate the power delivered to the UV-lamps, in order to save energy. In case of low UV intensity measured by the UV sensor, the system will reduce the flow in order to obtain the UV dose.

3.1.4 Operating principles

When starting the ballast and de-ballast operation the UV lamps need an approx. 2 minutes warm up period. When starting the ballast operation and after the warm up period has been completed, the ballast pump is started and the valves to the chosen ballast tank are opened and the operation starts. When starting de-ballast operation, again after warm up period completed, the ballast pump is started and the chosen ballast tank valve is opened as well as overboard valve and the operation takes place.

Closing of both ballast and de-ballast operation is reverse of start. The ballast pump and relevant valves for moving water into or out of the ballast tank are closed.

The filtering system consists of a valve system for in- and outlet and filter back flushing. This may include a back flush pump if the installation position requires extra flushing pressure to move the back flush water over board. The filter has a pore size of 30 micron and is able to remove a large quantity of the suspended solids. In order to assure maximum capacity of the filter an air bleeding valve is installed on the top of the filter, this ensures a water filled filter and maximum capacity.

The filter is self-cleaning and the material from the ballast water trapped in the filter will be pumped back to the sea/harbour. The cleaning process takes place during operation, meaning that the ballast water flow is continuous. The pressurized filter is a mechanical self cleaning mesh filter. The filter segments are built up in a cylindrical form with separate filter mesh rods. The filter is self cleaning and operated by differential pressure measurement. The filter rods are cleaned successively and allowing the filter to be in operation during cleaning mode. Pressurized water is back flushing the filter mesh and the contaminated cleaning water is guided to the sea/harbor.

In filtration mode the ballast water is pumped to the filter elements. Particles larger than 30 micron are removed and retained on the external surface of the screens. The filtered water leaves via the outlet connection. When the differential pressure between the dirty and clean sides of the filter increases to approx. 0.5 bar, this will be registered by a differential pressure transmitter and the control unit will start a back flushing cycle until the differential pressure reaches approx. 0.35 ,which ends the back flushing operation. The pressure inside the filter will not be less than 1.5 bars and having access to the atmosphere the cleaning of the filter is very efficient. Again, the cleaning procedure takes place while the filter still is in operation. The water used for cleaning the filter is directed overboard resulting in the fluctuation of flow into the UV-unit during the process. When the filter is not cleaning itself the flow is more stable and instantly when starting the cleaning process the flow through the UV-unit will be lower. The average flow into the UV-unit depends on the water quality of the inlet water.

As mentioned the flush water is discharged into the harbor again, when it is the ballast procedure. The fact that the filter could not be used when de-ballasting has become a fact in the industry. However, when being forced to find new solutions for being able to have a so-called mechanical system being able to fulfill the G8 requirements in fresh water the use of the mechanical filter also when de-ballasting became obvious.

DESMI Ocean Guard has submitted a patent application for the concept where the filter flushing water is guided to the suction side of the ballast pump during de-ballast operations. The main concern when testing the concept was minerals (sand) still being left in the treated water which after a certain period could block the filter when de-ballasting. However, tests have shown that all minerals larger than the filter mesh (30 micron) are removed already during ballast operation because these particles cannot squeeze through the filter. Organisms larger than 30 micron left for the de-ballast operation are purely organic compounds which have been able to squeeze through the filter during the ballast operation. These will be destroyed and become smaller particles after hitting the filterscreen one – two or more times and finally passing the filter. Depending on the water quality the period between the filter cleaning cycles will be very different, from constant cleaning to many minutes.

3.2 The theory of the BWMS'operation

3.2.1 Principles

The DESMI Ocean Guard RayClean™ BWTS is composed of pre- and after-treatment modules to disinfect aquatic species in the ballast water. The treatment system comprises mechanical filtration in combination with ultraviolet radiation (UV).

The concept of RayClean™ is to use filtration and UV to treat ballast water. Due to the highly efficient filtration and UV radiation, the DESMI Ocean Guard technology can be viewed as a standalone unit that should not affect the ballast tank or the environment. Because the UVC technology is instantaneous very intense treatment of the water it can be considered as a one stop treatment, meaning there is no reaction time with risk of damage to the ballast water tanks.

3.2.2 Filtration under de-ballasting

In the RayClean™ system the filter is also used when de-ballasting. This way of using a pressurized filter in a ballast water treatment system is now submitted as a patent application. The major advantage of using the filter also when de-ballasting is that organic material with a size exceeding 30 micron will be stopped in the filter. The major problem with organisms in fresh water is that it is soft organisms contrary to many organisms living in salt water having a shield for protection, and the softer flexible freshwater organisms squeeze through the filter.

3.2.3 UV irradiation

Ultraviolet technology is proving more and more successful and is used as an acknowledged, cost-effective and reliable process. UV-C radiation as disinfection means is well known for almost a hundred years and is used widely in the disinfection of potable water, aquaculture waters, cooling water, hot water systems, ultra pure water, foodstuff industry, medicine, bottling of drinks, etc. It is used primarily wherever the microbiological requirements are particularly high, or where chemical disinfectants are unacceptable for quality or environmental reasons. It was found that especially a narrow band of wavelengths around 260 nanometer (nm) has a strong performance for disinfection, and are similar to the absorption curve of the DNA. The mono chromatic low-pressure mercury germicidal lamps, which are used for UV-disinfection in the RayClean™ system, have their maximum performance at a wavelength of 254 nm exactly in the optimal narrow band.

The use of UV-radiation as disinfection energy results in no change of the treated water's chemical compositions, ph-value, temperature, salinity, taste, odor and color, and safety issues related to the handling and storage of Active Substances or other chemicals are eliminated.

Ultraviolet disinfection requires a minimum dosage to be effective. The applied dosage is a function of the UV intensity and the exposure time. These parameters are directly affected by equipment configuration, flow path of the water along the bank of lamps and the turbidity (UV-transmission) of the water to be disinfected. Compared to mid- or high-pressure lamps, low-pressure lamps can only operate with lower power intensity, but they have a much higher efficiency up to 40%. Using high- or mid-pressure UV lamps, the operating costs will be higher but the number of needed lamps less.

It is a scientifically well-known fact that resistance of organisms like bacteria, viruses, moulds or fungal spores to ultraviolet radiation is not developed. Most pathogenic germs are especially sensitive to UV-radiation. An important advantage of physical disinfection is that the sensitivity to UV still functions even when germs have already built up resistance to conventional disinfection measures such as alcohol, antibiotics, chlorinated chemicals, etc.

To address all the mentioned needs, UV-radiation technology provides a powerful barrier to chemical contaminants while simultaneously disinfecting to avoid the dispersal of invasive aquatic species by ballast water from ships.

The primary effect on organisms through short-wave and energetic UVC radiation at 254 nm is based on a photo-chemical alteration of the DNA. The UVC radiation is absorbed by pyrimidins, which form the basic elements of the organic bases of the DNA string. Through covalent bindings of two neighboring bases like thymin, pyrimidin dimers are generated. These pyrimidin dimers prevent replication of DNA helix strings and cause mutations which result from unsuccessful DNA string repair mechanisms. Dimers are called "bulky lesions": they disturb the helical configuration of DNA by means of partial decartelization resulting in reduced base matching ability. In addition, the UV radiation may result in direct alterations of the DNA morphology, for example, singular or double string fractures. Double string fracture cannot be repaired and lead to cell mortality. In general, UV radiation results in defects of DNA repair abilities.

3.3 Process or technology limitations of the BWMS

The only known limitation of the BWMS is that the measured UV-Intensity inside the UV Unit should be greater or equal to 55 W/m2. If the intensity is below this level an alarm will be displayed on operators Panel.

3.4 Performance ranges and expectations of the system

3.4.1 Flowrate

The RayClean-300 BWMS system has a Treatement Rated Capacity (TRC) of 300 m3/h. The system is capable of operating at full flowrate as long as the measured UV-intensity inside the UV unit is not less than 165 W/m2. When the UV intensity is less than 165 W/m2 the flowrate is reduced in order to maintain the same minimum UV dose. The flow regulation is described in section 6.6.4.

3.4.2 Salinity

The system can treat all water salinities, from 0 PSU and upwards.

3.4.3 Temperature

The system can treat water with temperatures from 0 to 50 deg. C.

3.4.4 Performance

When operating the system within the above range of parameters and according to the operating procedures described in chapter 7, the RayClean system will comply with both IMO D2 discharge standards and the US Coast Guard discharge standards.

3.5 Locations and conditions for which the BWMS is intended

DESMI Ocean Guard RayClean BWMS is intended to be used for treatment of all 3 water salinities: fresh water, brackish water and salt water all around the world.

4 Major system components and shipboard application

4.1 Materials used for the BWMS

Under preparation – to follow

4.2 Fitting of major components

Under preparation – to follow

4.3 Where the BWMS is not intended to be used

Under preparation – to follow

4.4 Flow and volume capacities of the BWMS

The RayClean-300 BWMS has a Treatment Rated Capacity of 300 m3/h.

The internal volume of the filter is 280 liters and the internal volume of the UV unit is 430 liters.

4.5 Dimensions of the BWMS

Under preparation – to follow

4.6 Actual or potential effects of the BWMS

The RayClean™ system does not have any known actual or potential effect on the vessel's ballast water, ballast water tanks and ballast water piping and pumping systems.

4.7 Active substances to be used by the BWMS

No active substances are to be used by the RayClean™ BWMS.

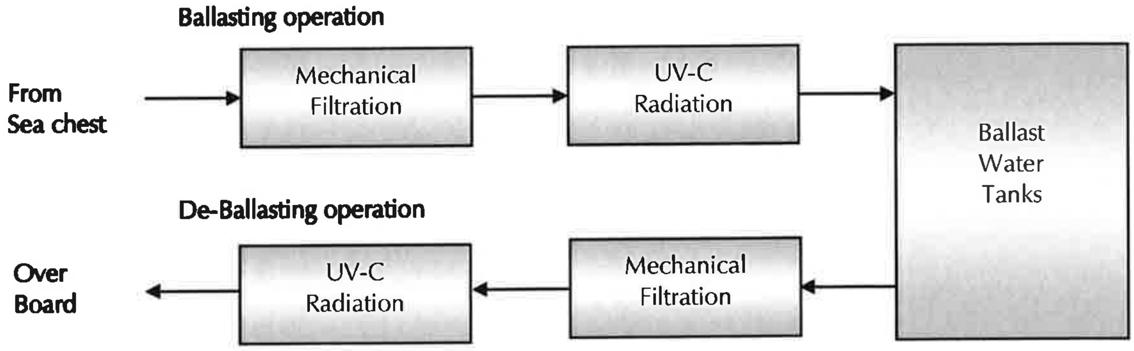
4.8 Installation and use of the BWMS in hazardous locations

The standard version of the RayClean™ system is NOT designed to be installed and used in hazardous locations.

5 System and major system component drawings as applicable

5.1 Process flow diagram(s) of the BWMS

The treatment method of RayClean™ BWMS is to use the combination of mechanical filtration and UV-C radiation to disinfect aquatic species in the ballast water. Due to the highly efficient filtration and UV-C radiation, the RayClean™ technology can be viewed as a standalone unit that does not affect the ballast tank or the environment. Because the UV-C technology is instantaneous and very intense treatment of the water there is no required minimum retention time.



5.2 Footprints, drawings, and system schematics
Under preparation – to follow

5.3 DRWG's & BOM's for pumping and piping arrangements
Will be prepared specific for each sold project

5.4 Treatment application points, waste or recycling streams and sampling points
Under preparation – to follow

5.5 Connection points to the BWMS
Under preparation – to follow

5.6 Electrical wiring diagrams
Under preparation – to follow

5.7 TAG Numbering / Identification
Under preparation – to follow

5.8 Index of all drawings and diagrams
Under preparation – to follow

6 The BWMS's control and monitoring equipment
A description of the BWMS's control and monitoring equipment and how it will be integrated with the existing shipboard ballast system – Under preparation – to follow.

6.1 Power demand
Under preparation – to follow

6.2 Main and local control panels
In this installation there is only one control panel (Main), placed on the Main control box inside the container.

6.3 Power distribution system

Under preparation – to follow

6.4 Power quality equipment

Under preparation – to follow

6.5 Instrumentation and control system architecture

Under preparation – to follow

6.6 Process control description

6.6.1 Essential components

The DESMI Ocean Guard – RAYCLEAN is a combination of filtration and low pressure UV. The system that will be tested is a 300 m³/h and the scalability lies in the 300 m³/h UV unit, meaning that systems from 1 – 300 m³/h needs one UV unit, systems from 301 – 600 m³/h needs two UV units and so on.

Essential components in the system:

- Filter: Mechanical 30 µm candles
- UV: 325 W low pressure UV lamp (100 W UVC output)
- Electrical control cabinet with a PLC, able to control 1-10 UV units (Master)
- Electrical UV cabinet (UVCP)

The test configuration is illustrated in the figure below.

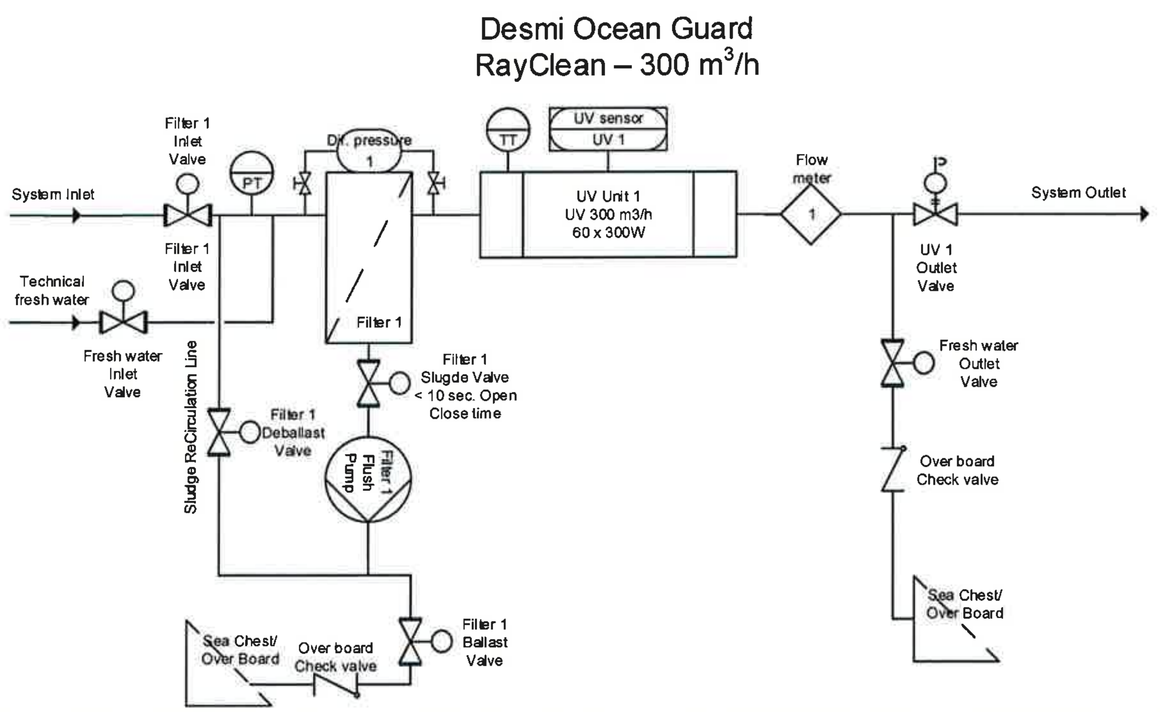


Figure 1. Generic PI-diagram, with regard to different combination components allowing the system to be fitted to flows between 1 - 300 m3/h.

6.6.2 The ballast operation process

The ballasting process is initiated by pressing "start ballast operation" on the PLC panel, which will start the following procedure:

- The UV-unit is turned on, the lamps has a preheating time of 120 seconds, after which the pump is released.
- The "Filter 1 Inlet Valve" will open, the "UV 1 Outlet Valve" will open and the "Filter 1 Ballast Valve" will open (directing back flush water *overboard* during back flush procedure).
- The ballast pump is turned on.
- The Filter control is active; meaning that during operation the filter will build up pressure drop, resulting in a back flush procedure. The pressure drop over the filter is measured by a differential pressure transmitter, which is used to maintain a differential pressure over the filter between approx. 0,35 – 0,5 bar. The back flushing procedure is activated at a differential pressure of 0,5 and deactivated at a differential pressure of 0,35.
- The back flush procedure, include: "Filter 1 sludge valve" will open, "Filter 1 flush pump" will start (if installed, it is only installed if the back pressure of the piping system is too big).
  - The pump is not installed in the Land based test system.
  - The pump is installed in the Ship board test system.
- In order to ensure a sufficient treatment the system is using flow regulation, resulting in reduced flow during treatment of dirty water. In very clear water UV dimming ensures energy saving. The regulation curve is described in section 0.
- The system will run until the ballasting process is ended by pressing "shutdown ballast operation" on the PLC panel, which will start the following procedure:
- The ballast pump in turned off.
- Cleaning begins (This procedure can be postponed on the PLC, if the ballasting process is stopped temporarily):
- The "Filter 1 Inlet Valve" will close, the "UV 1 Outlet Valve" will close.
- The internal mechanical cleaning will begin, further described in section 6.6.5.
- Fresh water refilling will begin, further described in section 6.6.6.
- When all internal mechanical cleaning and fresh water refilling is done all valves closes and the system is in stand by and ready for a new operation.

6.6.3 The deballast operation process

The deballast process is initiated by pressing "start deballast operation" on the PLC panel, which will start the following procedure:

- The UV-unit is turned on, the lamps has a preheating time of 120 seconds, after which the pump is released.
- The "Filter 1 Inlet Valve" will open, the "UV 1 Outlet Valve" will open and the "Filter 1 Deballast Valve" will open (directing back flush water is directed *back into the filter through the sludge recirculation line*).
- The ballast pump is turned on.
- The Filter control is active; meaning that during operation the filter will build up pressure drop, resulting in a back flush procedure. The pressure drop over the filter is measured by a differential pressure transmitter, which is used to maintain a differential pressure over the filter between approx. 0,35 – 0,5 bar. The back flushing procedure is activated at a differential pressure of 0,5 and deactivated activated at a differential pressure of 0,35.
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  - The pump is not installed in the Land based test system.
  - The pump is installed in the Ship board test system.
- In order to ensure a sufficient treatment the system is using flow regulation, resulting in reduced flow during treatment of dirty water. In very clear water UV dimming ensures energy saving. The regulation curve is described in section 0.

- The system will run until the ballasting process is ended by pressing "shutdown deballast operation" on the PLC panel, which will start the following procedure:
- The ballast pump in turned off.
- Cleaning begins (This procedure can be postponed on the PLC, if the ballasting process is stopped temporarily):
- The "Filter 1 Inlet Valve" will close, the "UV 1 Outlet Valve" will close.
- The internal mechanical cleaning will begin, further described in section 6.6.5.
- Fresh water refilling will begin, further described in section 6.6.6.
- When all internal mechanical cleaning and fresh water refilling is done all valves closes and the system is in stand by and ready for a new operation.

6.6.4 Flow regulation and UV dimming:

Flow regulation ensures treatment of very dirty water, with regard to UV-Transmission (UVT) and UV dimming ensures energy savings in clear water.

The water quality affects the UVT and the intensity of UV measured by a UV intensity sensor. The DESMI Ocean Guard RayClean™ system will regulate on UV effect and water flow in order to treat the water with a minimum UV-dose, independent of water quality and UVT.

The water quality varies a lot, and in harbors located at a river estuary, the water quality can be very poor, in which case the UVT is low. The opposite is a situation in high salinity water at sea, where the water quality can be very good and the UVT high.

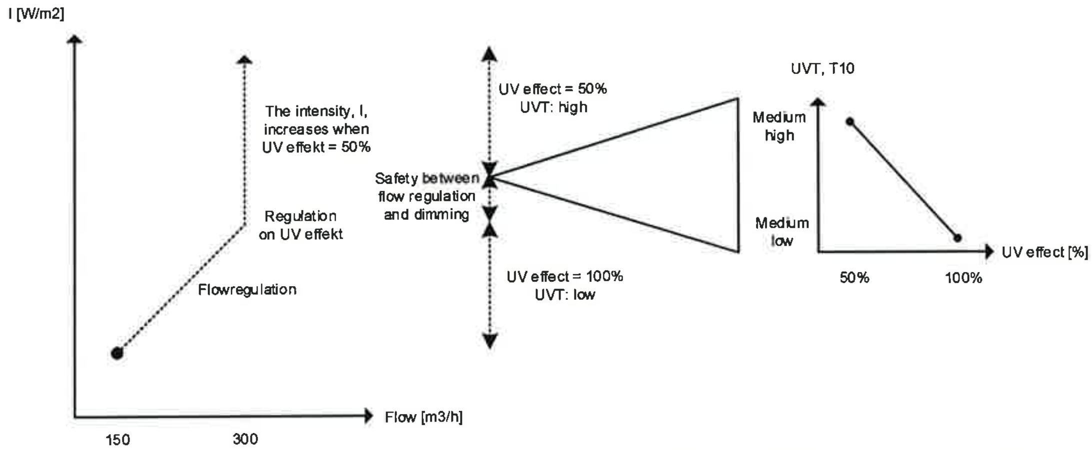


Figure 2. An example of how flow regulation and UV dimming will ensure a full treatment range with regard to water quality and maximum utilization of equipment and energy.

The system is designed to be flexible and use the energy needed for treatment in a given water quality.

- *Low UVT*: The measured UV intensity is low. Flow regulation between 100 – 300 m^3/h will be used to extend the time in which the water is in contact with UV light, thus giving the right treatment.
- *Medium low to medium high UVT*: In order to give the right treatment and save energy the UV-lamps input power is regulated (UV lamps are "dimmed") between 50 and 100%.
- *High UVT*: When the UVT reaches a certain level the intensity and UV-dose will rise, because the UV-lamp input power cannot regulate lower than 50%.

This regulation enables a very large UVT range with compliant treatment as well as energy saving possibilities.

6.6.4.1 RayClean Control Curve

The parameters of flow regulation and dimming control curve is shown below in Table 1. The dimming set point is denoted "300d", this is the value that the control system will try to maintain if the water is very clear. The flow regulation set point is denoted "300" and this is the value where the flow regulation begins. If the intensity is between the two values represented by "300" and "300d" the flow set point Is 300 m^3/h and the dimming is set point is 100%. The flow regulation systems lowest set point is denoted "100" referring to 100 m^3/h.

Table 1. Control curve parameters.

Flow m^3/h	*Intensity* [W/m^2]
300d	200
300	165
100	55

The parameters of Table 1 is illustrated as the control curve below

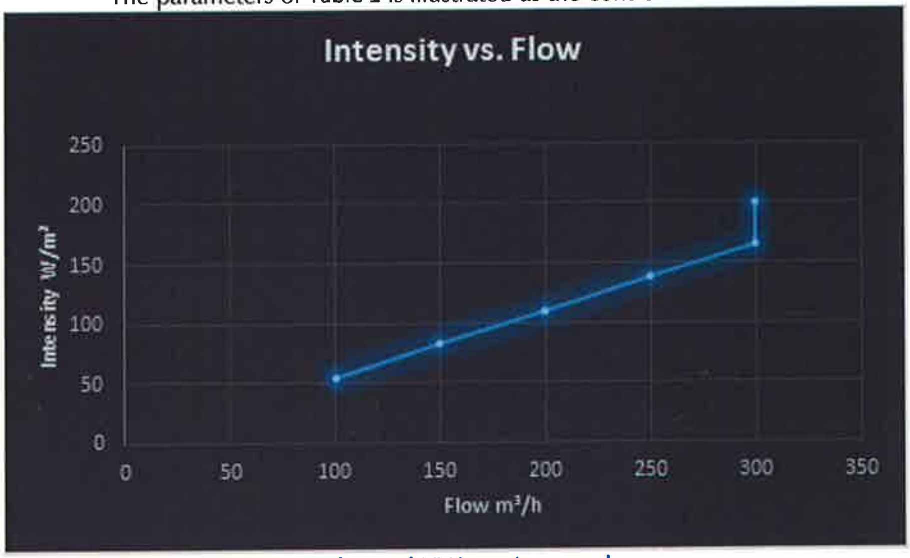


Figure 3 Flow and UV intensity control curve

The system control curve is illustrated and the flow curve can be described as:

I = 0.55*F

For F = [100...300]

Where F = flow and I = intensity

Dimming set point is I = 200 W/m^2 for F = 300 m^3/h

6.6.5 Internal mechanical cleaning of the UV-unit

The UV-unit has an internal mechanical cleaning system that is activated as a part of the shutdown procedure. The system consists of a plate with 60 Teflon rings, one around each quartz tube. A spindle is mounted in each end of the UV unit, in the inlet end the spindle is mounted in a hub a in the other end a servo drive in fitted. The servo drive is used for moving the plate and thereby cleaning the quartz tubes, because the Teflon rings has the function for a scraper. Furthermore the servo drive is used as a positioner, when the system is starting up, the servo is making a homing procedure where it finds the end position, enabling it to be placed anywhere in the UV unit. During operation the plate is positioned 400 mm from the flat end of the UV-unit by moving it 320 mm with the servo drive, illustrated in Figure 4. This is done in order to optimize the hydraulics of the UV-unit.

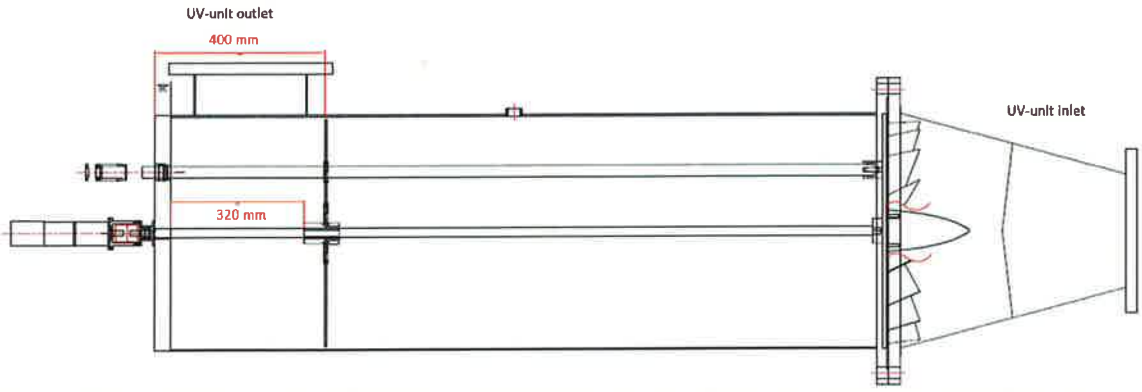


Figure 4. UV-unit with illustrated position of the mechanical cleaning plate / hydraulic optimizer, during ballast and deballast operation

The cleaning plate design is illustrated in Figure 5.

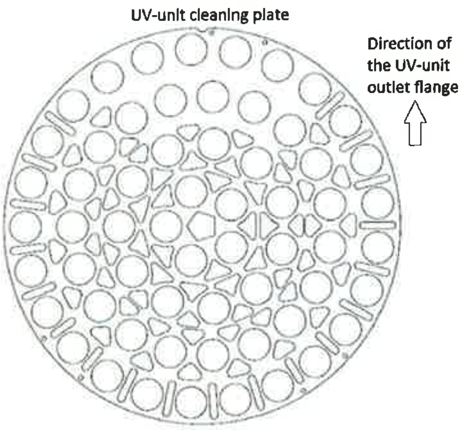


Figure 5. Design of the mechanical cleaning plate / hydraulic optimizer.

6.6.6 Freshwater refilling system

The fresh water refilling system is an automatic water exchange system, which is activated during the shutdown procedure. Technical fresh water is directed into the system at the filter by opening the "fresh water inlet valve" and the treated water is directed out of the after the UV-unit b opening the "fresh water outlet valve". If it is a deballast operation the UV lamp are turned on during this operation, in order to ensure treatment compliance. Either a value of 10 PSU from the salinity meter or a timer ends the refilling procedure. The procedure can be stopped manually at any time, but freshwater flushing after each ballast or de-ballast operation is recommended primarily in order to minimize corrosion risk.

6.7 Set points, loops, algorithms and alarm settings

Operational set points, control loops, control algorithms, and alarm settings for routine maintenance, and emergency operations. **Under preparation – to follow**

6.8 Devices required for measuring appropriate parameters

All devices required for measuring appropriate parameters, such as pressure, temperature, flow rate, water quality, power, and chemical residuals. **Under preparation – to follow**

7 Standard operating procedures

7.1 BWMS start-up and shutdown procedures and times

7.1.1 General

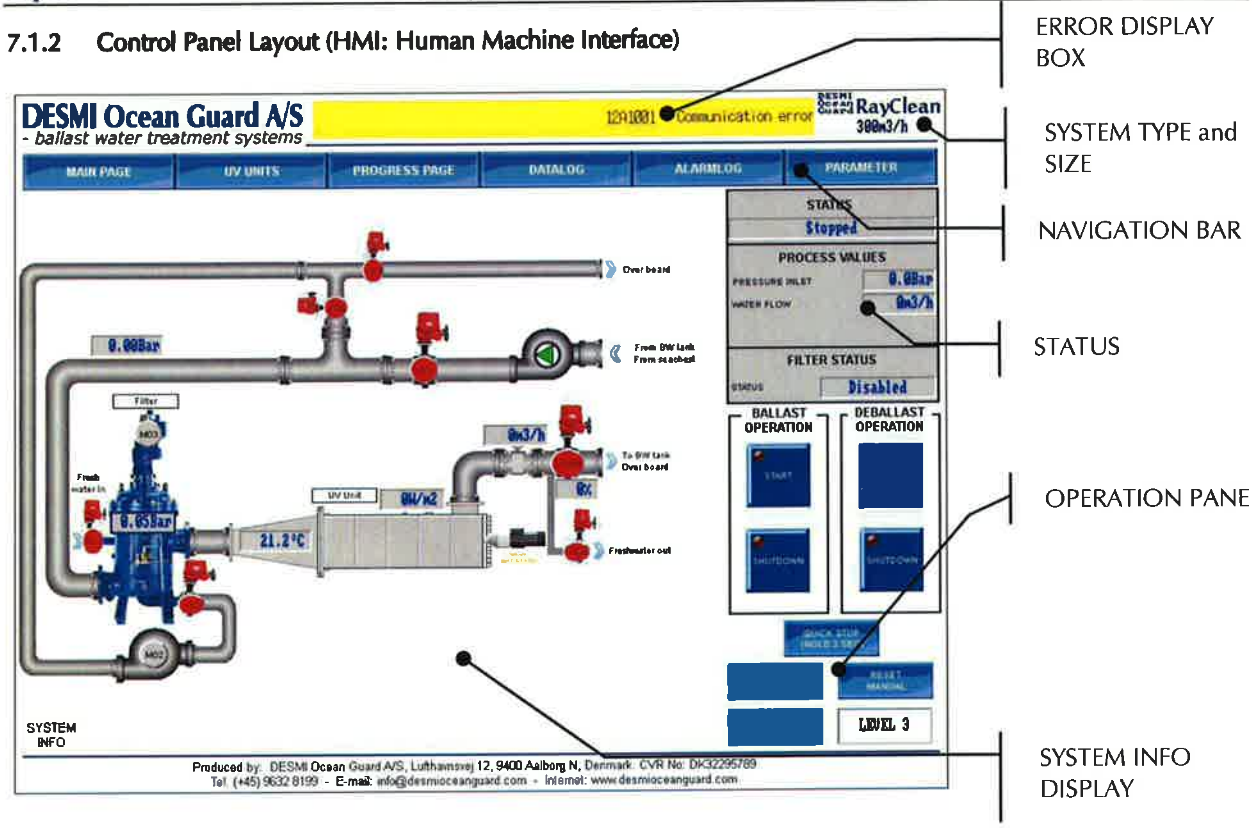
The RayClean™ BWMS consist of the following main components:

- Mechanical Filter
- UV reactor
- UV control cabinet for the lamp drivers placed at UV reactor
- Main control cabinet for operating the system

The system are fully automated and all control can be performed by one operator on the main Control panel (HMI: Human Machine Interface) placed in the Main Control Cabinet.

Standard operations are:
- Start-up Ballast Operation
- Shut-down Ballast Operation
- Start-up De-Ballast Operation
- Shut-down De-Ballast Operation
- Emergency shutdown
- By-pass operation

7.1.2 Control Panel Layout (HMI: Human Machine Interface)



7.1.2.1 NAVIGATION BAR

press buttons are used to choose and display MAIN PAGE, UV UNITS, DATA LOG and ALARM LOG the content in the Systems Info window(2).

7.1.3 SYSTEM INFO DISPLAY

Displays system information screens, chosen in the navigation bar

7.1.3.1 MAIN PAGE DISPLAY

Shows components and their current values or states

Pressure gauge inlet in bar gauge

On/off valve(s) (V01, V04, V05, V06) – Red: closed, Green: open, Gray: in moving position, Blinking Blue: Manual mode

Modulating valve (MV1) – Red: closed, Green: open + Opening %.

Pump Motors – Green: running, Grey: stopped and Yellow: failure mode.

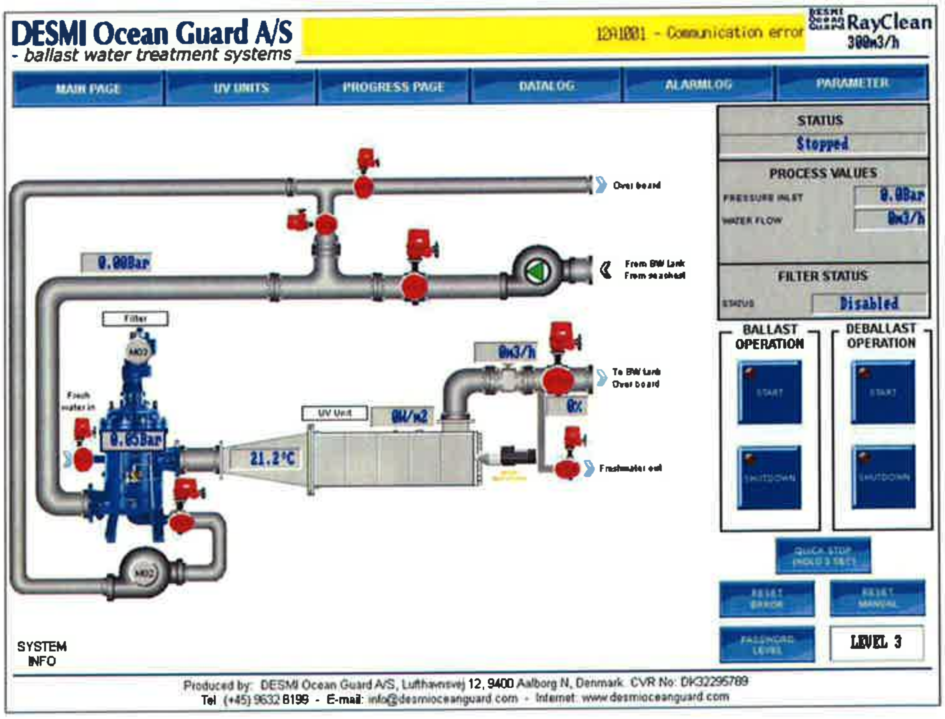
Filter differential Pressure in bar for filter

Inlet temperature in UV unit

UV intensity meter in UV unit

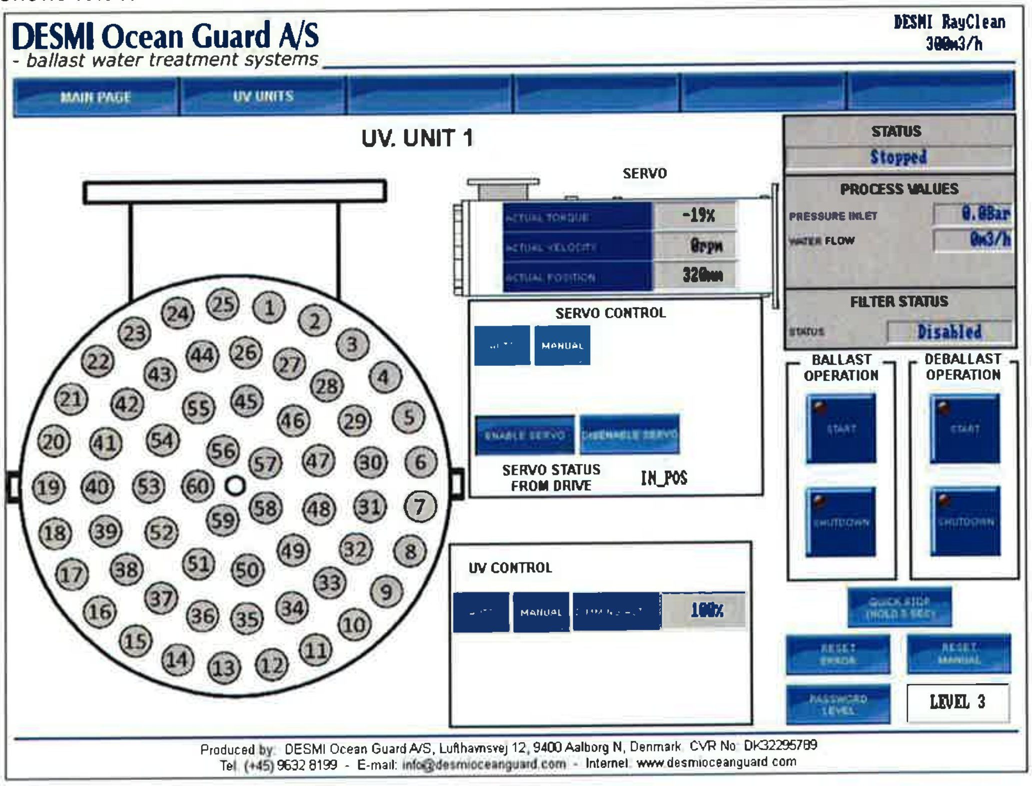
Flow meter on outlet side of UV unit

Pressure gauge inlet in bar gauge



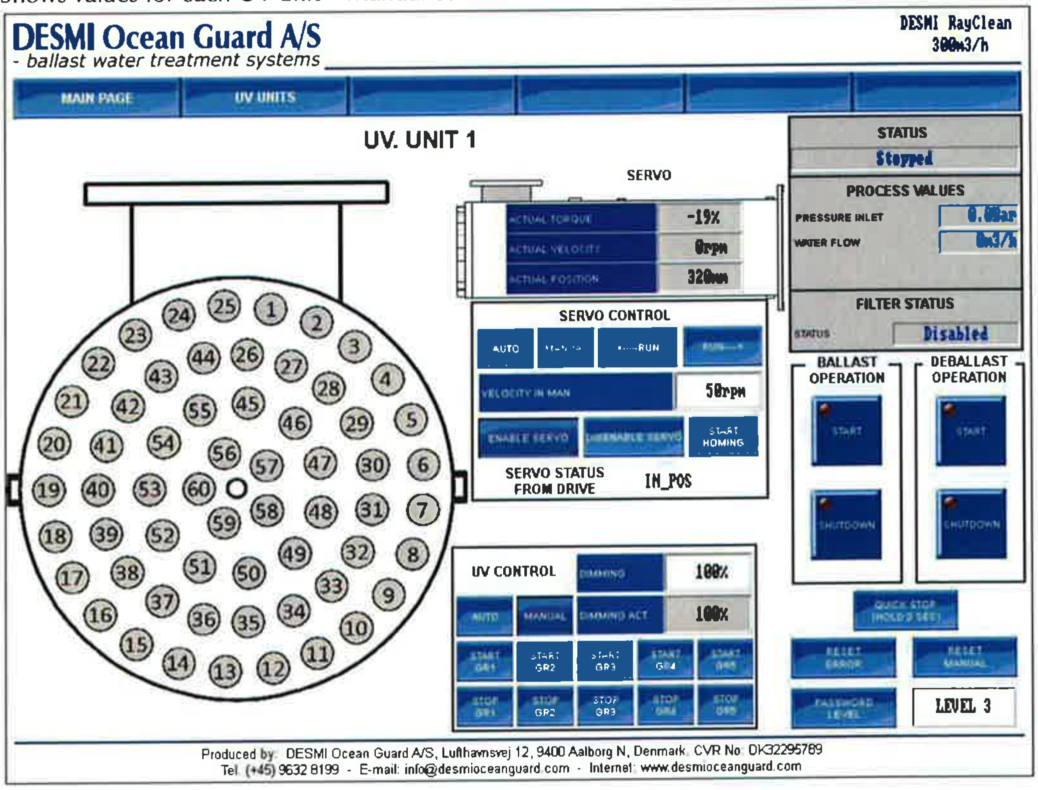
7.1.3.2 UV UNITS DISPLAY - Status

Shows values for each UV unit.



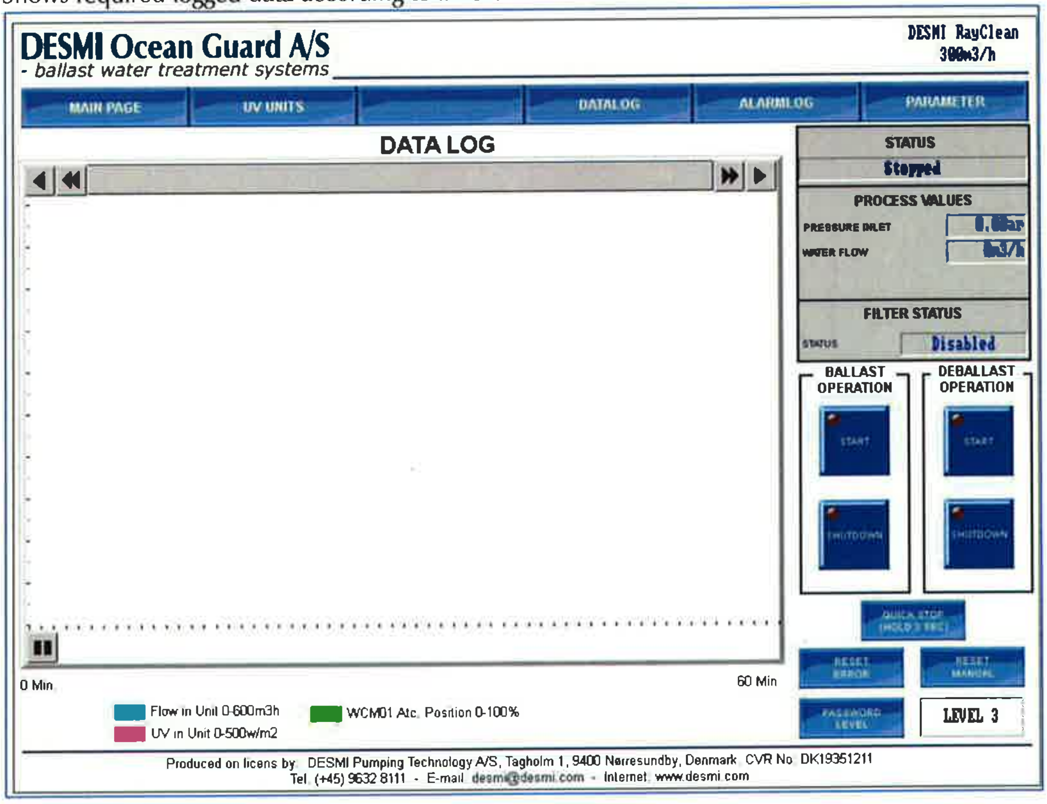
7.1.3.3 UV UNITS DISPLAY – Manual operation

Shows values for each UV unit – Manual control of UV unit and servo drive (for mechanical cleaning)



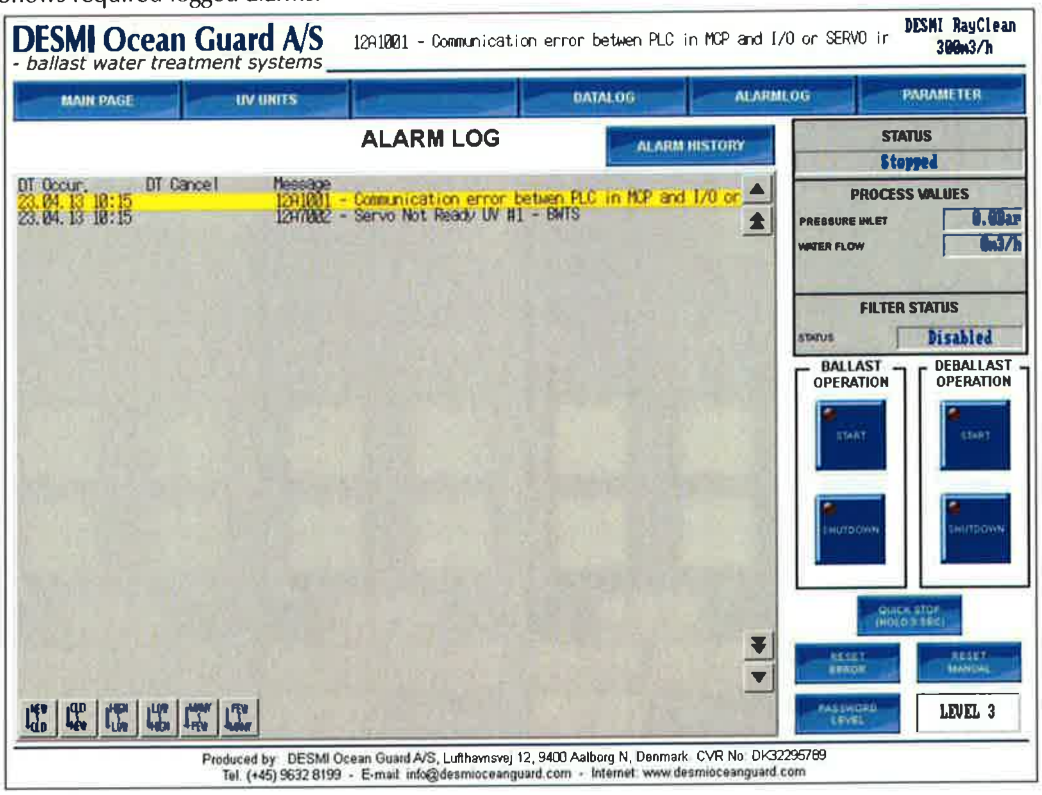
7.1.3.4 DATA LOG DISPLAY

Shows required logged data according to IMO and USCG rules.



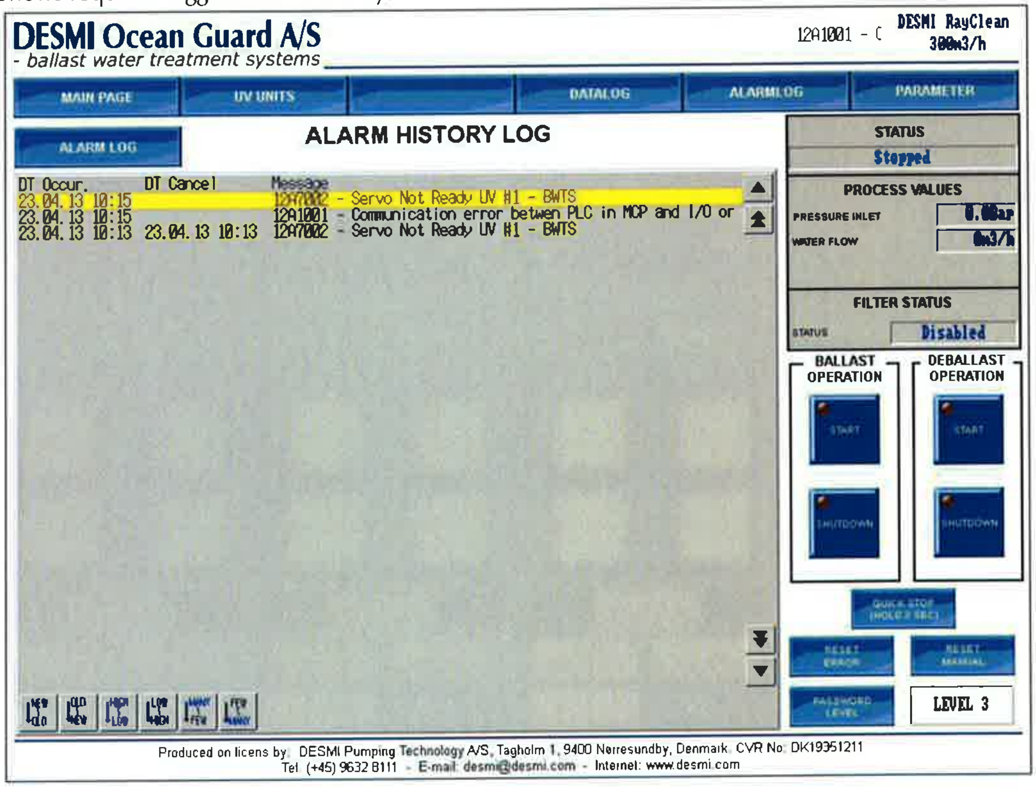
7.1.3.5 ALARM LOG DISPLAY

Shows required logged alarms.



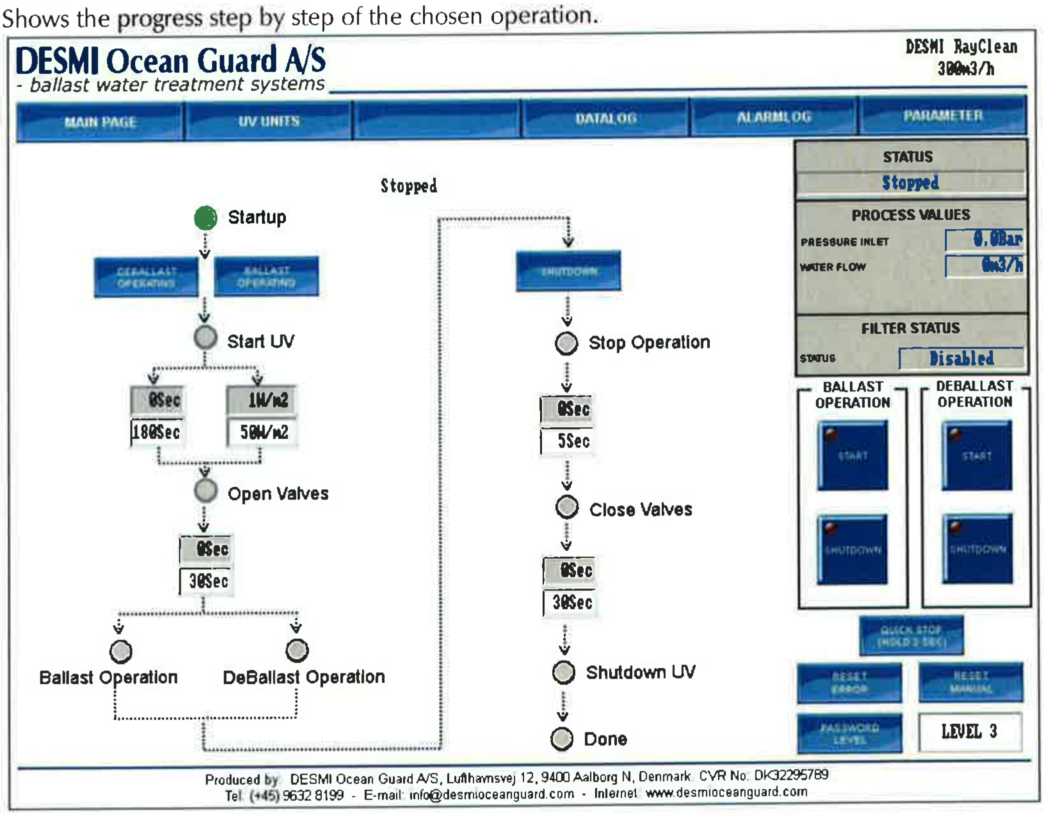
7.1.3.6 ALARM LOG HISTORY

Shows required logged alarms history.



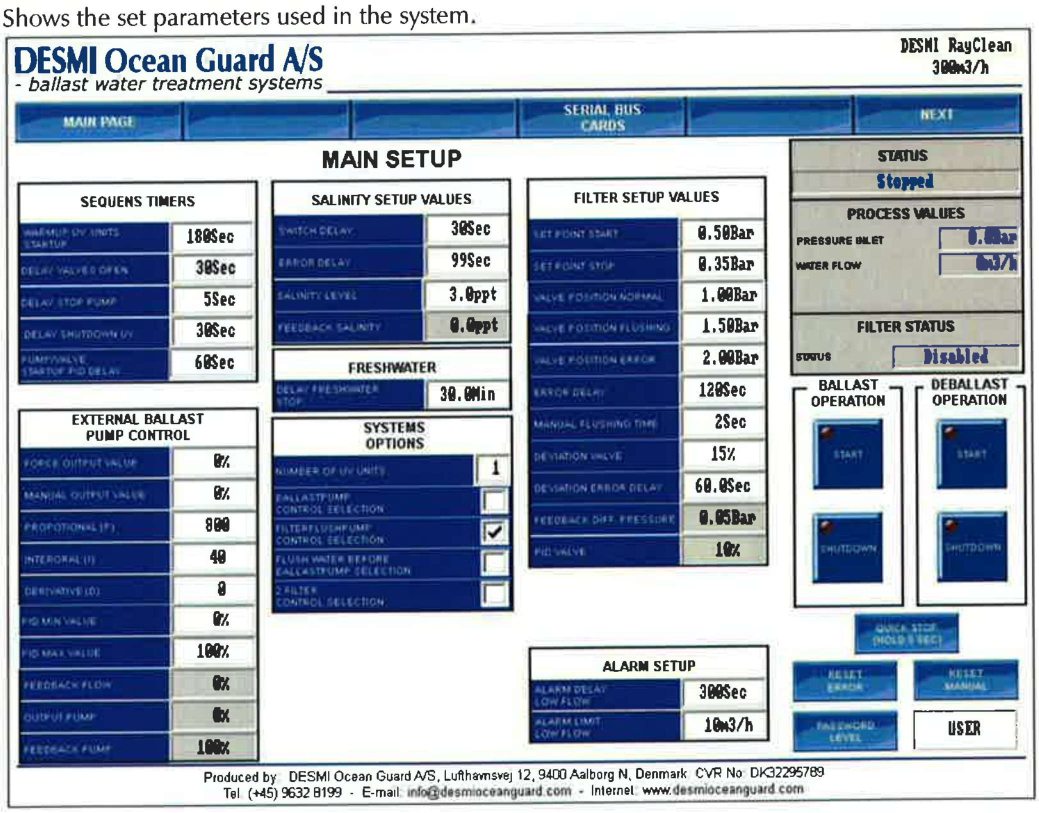
7.1.3.7 PROGRESS PAGE DISPLAY

Shows the progress step by step of the chosen operation.



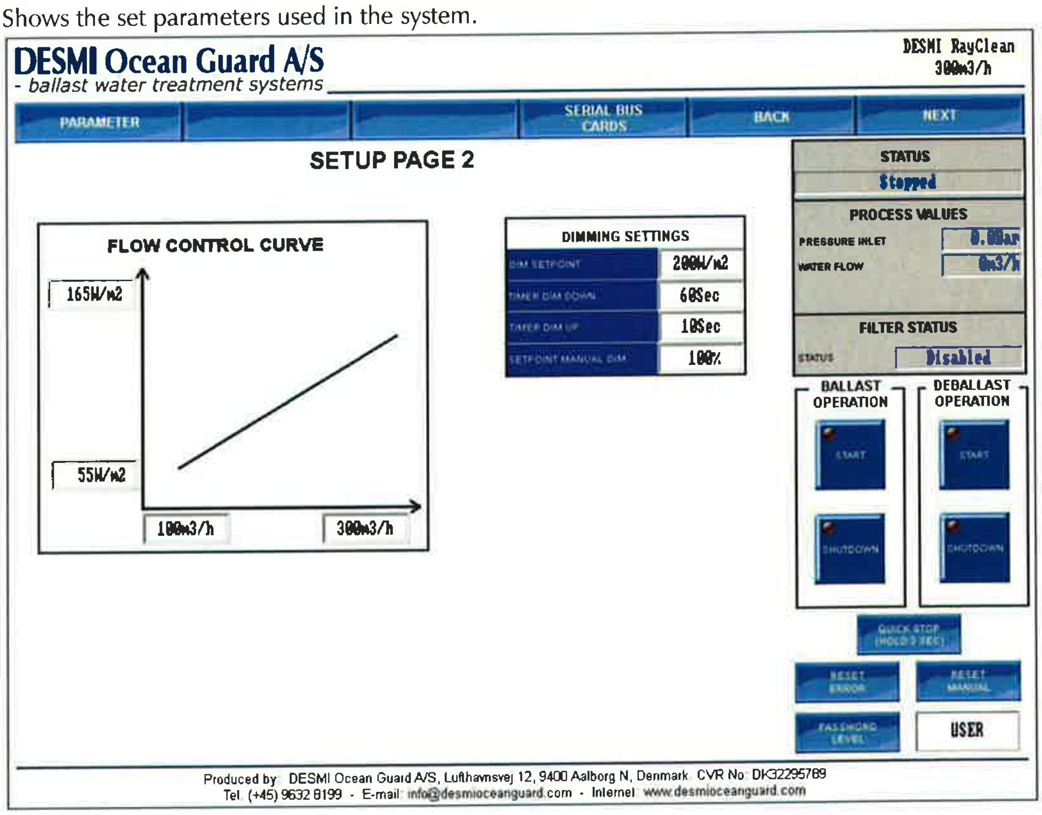
7.1.3.8 SET PARAMETERS DISPLAY – MAIN SETUP PAGE

Shows the set parameters used in the system.



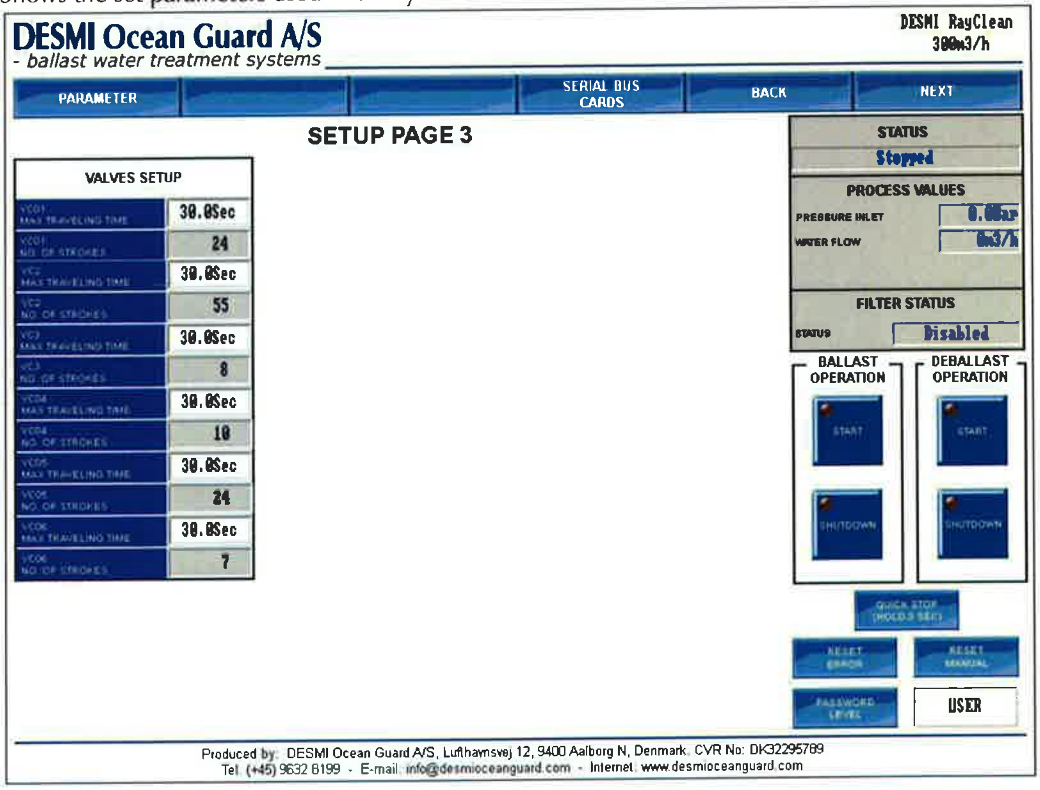
7.1.3.9 SET PARAMETERS DISPLAY – SETUP PAGE 2

Shows the set parameters used in the system.



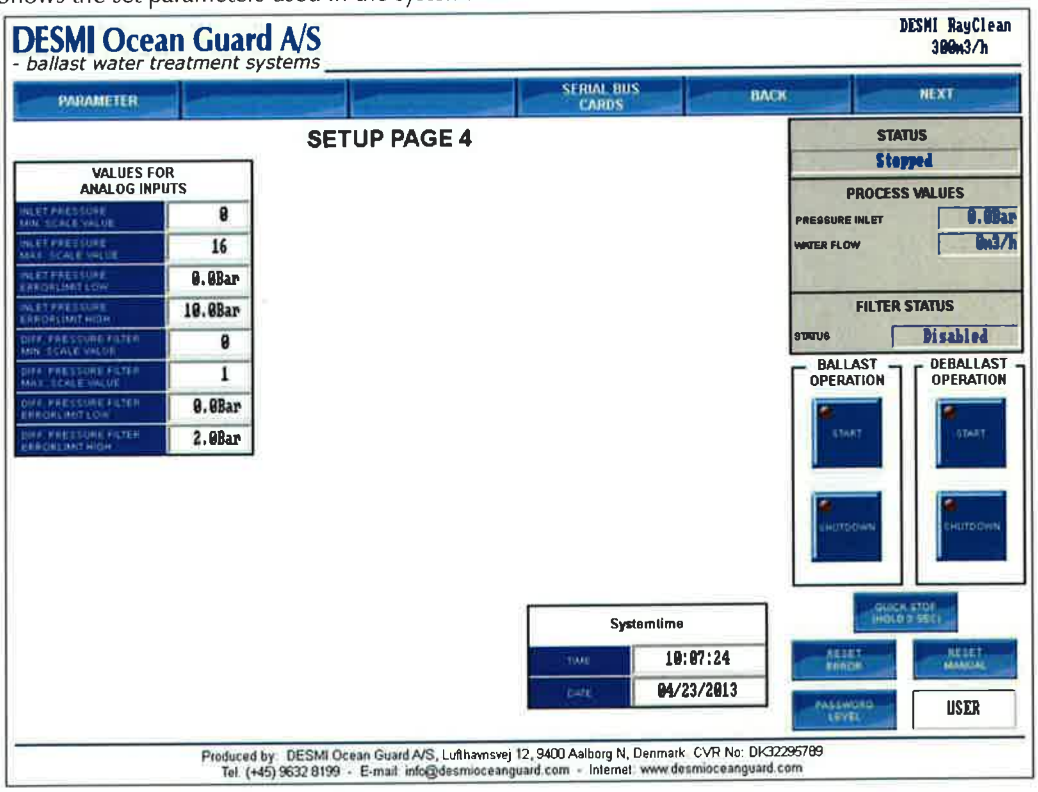
7.1.3.10 SET PARAMETERS DISPLAY – SETUP PAGE 3

Shows the set parameters used in the system.



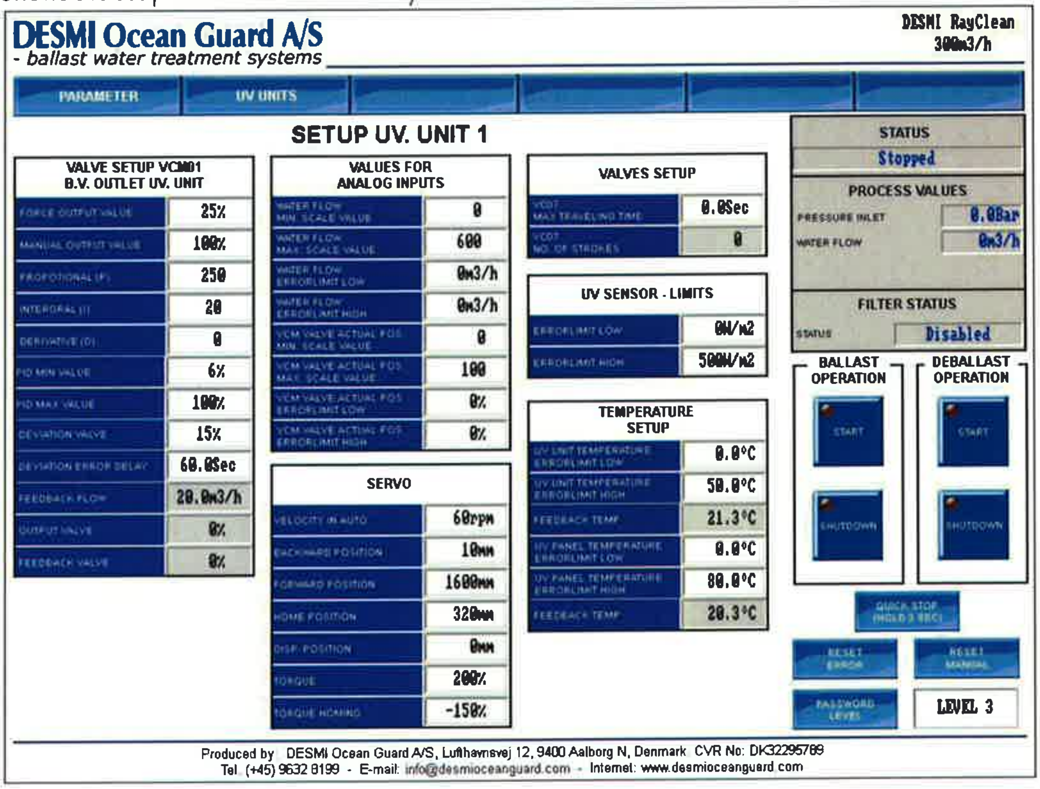
7.1.3.11 SET PARAMETERS DISPLAY – SETUP PAGE 4

Shows the set parameters used in the system.

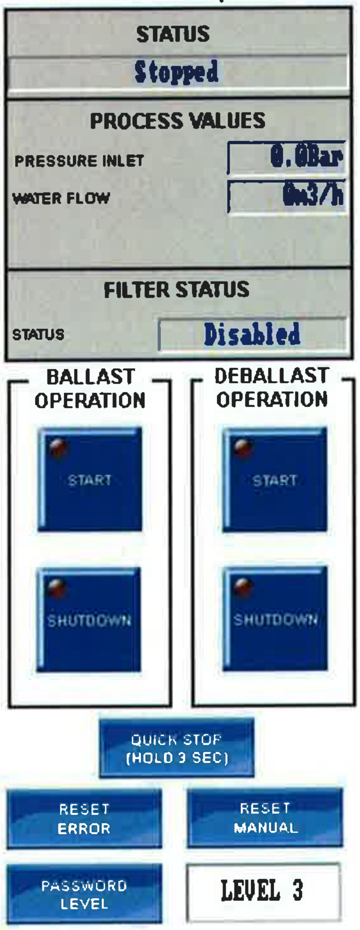


7.1.3.12 SET PARAMETERS DISPLAY – SETUP UV UNIT 1

Shows the set parameters used in the system.



7.1.4 Status and operation buttons window – Visible at all times



STATUS:	**Possible statuses**
BWMS status:	By-pass operation, Ballast warm up, Ballast operation, Deballast warm up, Shutting down, Stopped, Failure Mode, Power up - Cleaning UV, Manual operation, Manual FRW flush.
BYPASS VALVE:	OPEN, CLOSED; MOVING (By-pass operation active when OPEN).
FILTER STATUS:	OK or OK – Backflushing or Failure
SALINITY STATUS:	Fresh water, Salt Water

OPERATION:	
START BALLAST OPERATION:	Starts up ballast operation
SHUT DOWN BALLAST OPERATION:	Shut down ballast operation
START DEBALLAST OPERATION:	Starts up de-ballast operation
SHUT DOWN DEBALLAST OPERATION:	Shut down de-ballast operation
QUICK STOP (HOLD 3 SEC.)	Emergency Stop.
RESET ERROR	Resets error displayed in top (4.)
LOGIN	Login for the system in 4 levels: Level 0: Operator test conditions Level 1: Operator onboard/customer Level 2: Super user onboard/customer Level 3: DESMI Super user
DISPLAY BOX	Displays the logged in user.

7.1.5 ERROR DISPLAY BOX

Showing error codes and descriptions, See Error list below.

7.1.5.1 ALARM ERROR LIST

AlarmID - Alarm Message
12A0001 - Error in I/O card
12A0002 - Error in PLC
12A0003 - Error Battery in CPU In Control Panel
12A1001 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#1
12A1002 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#2
12A1003 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#3
12A1004 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#4
12A1005 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#5
12A1006 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#6
12A1007 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#7
12A1009 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#8
12A1009 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#9
12A1010 - Communication error betwen PLC in MCP and I/O or SERVO in UVCP#10
12A4001 - M01 Ballast pump fault

AlarmID - Alarm Message
12A4002 - M01 Ballast pump Missing feedback from contactor
12A4003 - M02 Flush pump 1 fault
12A4004 - M02 Flush pump 1 Missing feedback from contactor
12A4005 - M03 Flush arm 1 fault
12A4006 - M03 Flush arm 1 Missing feedback from contactor
12A4007 - M04 Flush pump 2 fault
12A4008 - M04 Flush pump 2 Missing feedback from contactor
12A4009 - M05 Flush arm 2 fault
12A4010 - M05 Flush arm 2 Missing feedback from contactor
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A4008 -
12A2005 - Alarm - Vaccum flow meter fault - BWTS
12A2006 - Alarm - No vaccum flow – BWTS
12A2007 -
12A2008 -
12A2009 -
12A2040 - Bypass valve not Closed
12A2041 -
12A2042 -
12A2043 - High ppm - BWTS
12A2044 - Low ppm - BWTS
12A7104 - No / missing water in flow meter - BWTS
12A7105 - Too high UV concentration - BWTS
12A7106 - Too high UV concentration - BWTS
12A7121 - - BWTS
12A7122 - Error Battery in CPU - BWTS
12A7123 - Error in PLC - BWTS
12A7204 - No / missing water in flow meter - BWTS
12A7205 - Too high UV concentration - BWTS
12A7206 - Too high UV concentration - BWTS
12A7221 - Fault MODBUS communication - BWTS
12A7222 - Error Battery in CPU - BWTS
12A7223 - Error in PLC - BWTS

AlarmID - Alarm Message
12A7304 - No / missing water in flow meter - BWTS
12A7305 - Too high UV concentration - BWTS
12A7306 - Too high UV concentration - BWTS
12A7321 - Fault MODBUS communication - BWTS
12A7322 - Error Battery in CPU - BWTS
12A7323 - Error in PLC - BWTS
12A7404 - No / missing water in flow meter - BWTS
12A7405 - Too high UV concentration - BWTS
12A7406 - Too high UV concentration - BWTS
12A7421 - Fault MODBUS communication - BWTS
12A7422 - Error Battery in CPU - BWTS
12A7423 - Error in PLC - BWTS
12A7504 - No / missing water in flow meter - BWTS
12A7505 - Too high UV concentration - BWTS
12A7506 - Too high UV concentration - BWTS
12A7521 - Fault MODBUS communication - BWTS
12A7522 - Error Battery in CPU - BWTS
12A7523 - Error in PLC - BWTS
12A7604 - No / missing water in flow meter - BWTS
12A7605 - Too high UV concentration - BWTS
12A7606 - Too high UV concentration - BWTS
12A7621 - Fault MODBUS communication - BWTS
12A7622 - Error Battery in CPU - BWTS
12A7623 - Error in PLC - BWTS
12A7704 - No / missing water in flow meter - BWTS
12A7705 - Too high UV concentration - BWTS
12A7706 - Too high UV concentration - BWTS
12A7721 - Fault MODBUS communication - BWTS
12A7722 - Error Battery in CPU - BWTS
12A7723 - Error in PLC - BWTS
12A7804 - No / missing water in flow meter - BWTS
12A7805 - Too high UV concentration - BWTS
12A7806 - Too high UV concentration - BWTS
12A7821 - Fault MODBUS communication - BWTS
12A7822 - Error Battery in CPU - BWTS
12A7823 - Error in PLC - BWTS
12A7904 - No / missing water in flow meter - BWTS
12A7905 - Too high UV concentration - BWTS
12A7906 - Too high UV concentration - BWTS
12A7921 - Fault MODBUS communication - BWTS
12A7922 - Error Battery in CPU - BWTS
12A7923 - Error in PLC - BWTS
12A8004 - No / missing water in flow meter - BWTS
12A8005 - Too high UV concentration - BWTS

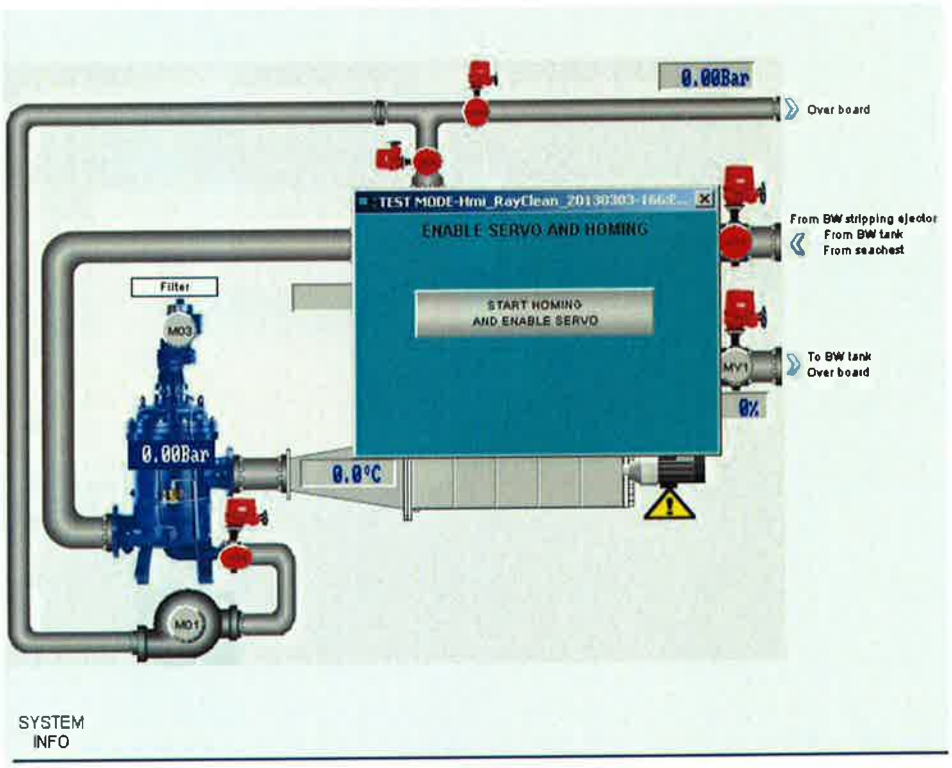
AlarmID - Alarm Message
12A8006 - Too high UV concentration - BWTS
12A8021 - Fault MODBUS communication - BWTS
12A8022 - Error Battery in CPU - BWTS
12A8023 - Error in PLC - BWTS
12A4003 - Filter flush pump fault
12A4004 - Missing feedback from contactor filter flush pump
12A4005 - Filter flush arm motor fault
12A4006 - Missing feedback from contactor filter flush arm motor
12A4007 - Air dryer fault
12A4008 - Missing feedback from contactor air dryer failure
12A2001 - Salinity sensor fault - BWTS
12A2002 - Salinity sensor - High alarm - BWTS
12A2003 - Salinity sensor - Lov alarm - BWTS
12A2004 -
12A2010 - Diff. Pressure transmitter fault - BWTS
12A2011 - High pressure filter - BWTS
12A2012 - Low pressure filter - BWTS
12A2013 -
12A2014 -
12A2015 - Temperature transmitter fault - BWTS Inlet
12A2016 - High temperature - BWTS Inlet
12A2017 - Low temperature - BWTS Inlet
12A2018 -
12A2019 -
12A2020 - Temperature transmitter fault - BWTS Outlet
12A2021 - High temperature - BWTS Outlet
12A2022 - Low temperature - BWTS Outlet
12A2023 -
12A2024 -
12A2025 - Pressure transmitter fault - BWTS Inlet
12A2026 - High pressure - BWTS Inlet
12A2027 - Low pressure - BWTS Inlet
12A2028 -
12A2029 -
12A2030 - Pressure transmitter fault - BWTS Outlet
12A2031 - High pressure - BWTS Inlet Outlet
12A2032 - Low pressure - BWTS Inlet Outlet
12A2033 -
12A2034 -
12A2035 - pH / REDOX transmitter fault - BTWS
12A2036 - High pH - BWTS
12A2037 - Low pH - BWTS
12A2038 -
12A2039 -

AlarmID - Alarm Message
12A2045 - Flow meter fault - BTWS
12A2046 - High flow - BWTS
12A2047 - Low flow - BWTS
12A2048 - No / missing water in flow meter - BWTS
12A3001 - Missing open feedback from valve VC-01 - BWTS Inlet valve
12A3002 - Missing closed feedback from valve VC-01 - BWTS Inlet valve
12A3003 - Both feedback sensors active VC-01 - BWTS Inlet valve
12A3004 - Missing open feedback from valve VC-02 - BWTS flush valve
12A3005 - Missing closed feedback from valve VC-02 - BWTS flush valve
12A3006 - Both feedback sensors active VC-02 - BWTS flush valve
12A3007 - Missing open feedback from valve VC-03 - BWTS Freshwater inlet valve
12A3008 - Missing closed feedback from valve VC-03 - BWTS Freshwater inlet val
12A3009 - Both feedback sensors active VC-03 - BWTS Freshwater inlet valve
12A3010 - Missing open feedback from valve VC-04 - BWTS Freshwater outlet valve
12A3011 - Missing closed feedback from valve VC-04 - BWTS Freshwater outlet val
12A3012 - Both feedback sensors active VC-04 - BWTS Freshwater outlet valve
12A3013 - Missing open feedback from valve VC-05 - BWTS flush Over board valve
12A3014 - Missing closed feedback from valve VC-05 - BWTS flush Over board valv
12A3015 - Both feedback sensors active VC-05 - BWTS flush Over board valve
12A3017 - Missing open feedback from valve VC-06 - BWTS flush Recirkulation val
12A3018 - Missing closed feedback from valve VC-06 - BWTS flush Recirkulation v
12A3019 - Both feedback sensors active VC-06 - BWTS Flush Recirkulation valve
12A3020 - Missing open feedback from valve VC-07 - BWTS
12A3021 - Missing closed feedback from valve VC-07 - BWTS
12A3022 - Both feedback sensors active VC-07 - BWTS
12A3023 - Missing open feedback from valve VC-08 - BWTS Outlet valve
12A3024 - Missing closed feedback from valve VC-08 - BWTS Outlet valve
12A3025 - Both feedback sensors active VC-08 - BWTS Outlet valve
12A3026 - Missing feedback from valve VCM-01 (Modulating) - BWTS outlet from fi
12A3027 - Both feedback sensors active VCM-01 (Modulating) - BWTS outlet from f
12A3028 - Missing feedback from valve VCM-02 (Modulating) - BWTS vaccum flow va
12A3029 - Both feedback sensors active VCM-02 (Modulating) - BWTS vaccum flow
12A7001 - No flow UV #1 - BWTS
12A7002 - Servo Not Ready UV #1 - BWTS
12A7003 - Too high flow UV #1 - BWTS
12A7007 - Fault a lamp driver in UV unit #1 - BWTS
12A7008 - Fault High temperature UV unit #1 - BWTS
12A7009 - Fault Low temperature UV unit #1 - BWTS
12A7010 - Fault High temperature UV Cabinet #1 - BWTS
12A7011 - Fault Low temperature UV Cabinet #1 - BWTS
12A7012 -
12A7013 -
12A7014 -
12A7015 -

AlarmID - Alarm Message
12A7016 - Missing open feedback from valve UV1.VC-01 - BWTS Inlet UV unit no. 1
12A7017 - Missing closed feedback from valve UV1.VC-01 - BWTS Inlet UV unit no. 1
12A7018 - Too long travling time for valve UV1.VC-01 - BWTS Inlet UV unit no. 1
12A7019 - Missing feedback from valve UV1.VCM-01 (Modulating) - BWTS Outlet UV Unit
12A7020 - Too long travling time for valve UV1.VCM-01 (Modulating) - BWTS Outlet UV

7.1.6 Power Up of the system

1) Check that all system components are intact and in place
2) Turn the Circuit breaker (Mains Switch) ON, connecting the power to the system.
3) Press the button START HOMING AND ENABLE SERVO in the pop up window.
   ⇨ The "START HOMING AND ENABLE SERVO" function establish communication with the mechanic cleaning of the quartz sleeves.



7.1.7 Start - Ballast Operation

7.1.7.1 Start up Sequence

1) Press the START button placed in "BALLAST OPERATION" pane.
   ⇨ The UV-lamp controllers are activated and the UV-lamps are heating up
   ⇨ When reaching the set temperature/time, valves V01, MV1, and V05 opens and the ballast pump motor starts.

   OBS! Press button PROGRESS PAGE to see the steps during start sequence on the system info screen.

7.1.7.2 Automatic functions active during ballast operation

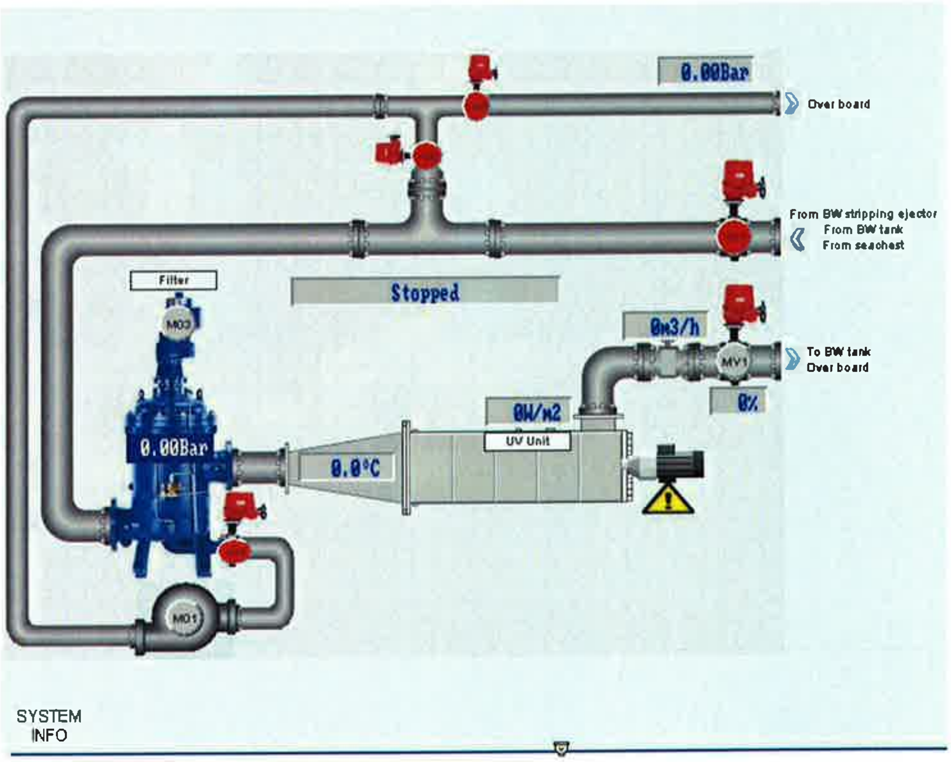
⇨ During the ballast operation, the differential pressure over the filter are measured and when the set point for the maximum allowable differential pressure are reached the valve V04 are opened and pump M01and M03 are started and the filter is cleaned by ack flushing.

⇨ When the set point for the minimum allowable differential pressure are reached the valve V04 are closed and pump M01and motor M03 is shot off.

7.1.8 Shut down - Ballast Operation

7.1.8.1 Shut down sequence

1) Press the SHUTDOWN button placed in "BALLAST OPERATION" pane.



⇨ Following pop up screen appears:

2) Choose when to start up mechanical cleaning of the UV Unit
   a. **START AFTER END OPERATION** starts up the mechanical cleaning for the quarts sleeves right after the ballast operation is finished.
   b. **START WITH DELAY** starts up the mechanical cleaning with the delay time to be specified in the **DELAY TIME** input box. This option is used when a ballast or deballast operation will take place within the time specified in delay time. **NB!** It's highly recommended of cleaning result purposes that the delay time doesn't exceed 60 minutes.

If the system will be used for ballast or deballast before the specified delay time is elapsed, the specified delay time will be re-set and the pop up screen will re-appear.

If the pop up window is ignored the mechanical cleaning process will be started automatically within 2 minutes.

The valves in the system are colored red. Further, the valves have a red circle as well. In case it is required/wanted that one or more valves are manually operated, the red circle is touched and a dialog box appears.

The main screen shows flow, pressure and temperature as well as UV intensity. Further the main screen shows filter status and whether the system operates in fresh or salt water.

7.1.9 Start - Deballast Operation

7.1.9.1 Start up Sequence

2) Press the START button placed in "DEBALLAST OPERATION" pane.
   - ⇨ The UV-lamp controllers are activated and the UV-lamps are heating up
   - ⇨ When reaching the set temperature/time, valves V01, MV1, and V06 opens and the ballast pump motor starts.

   OBS! Press button PROGRESS PAGE to see the steps during start sequence on the system info screen.

7.1.9.2 Automatic functions active during deballast operation

- ⇨ During the deballast operation, the differential pressure over the filter are measured and when the set point for the maximum allowable differential pressure are reached the valve V04 are opened and pump M01and motor M03 are started and the filter is cleaned by back flushing.
- ⇨ When the set point for the minimum allowable differential pressure are reached the valve V04 are closed and pump M01and motor M03 is shot off.

NOTE:
The RayClean System has a Ballast Operation sequence and a Deballast Operation sequence. The difference between the two modes is that during de-ballast the flush water from the filter will be re-circulated flush water into the system. When ballasting the flush water is pumped overboard.

7.1.10 Shut down - Deballast Operation

7.1.10.1 Shut down sequence

1) Press the SHUTDOWN button placed in "DEBALLAST OPERATION" pane.
   - ⇨ See the shut down - Ballast operation.

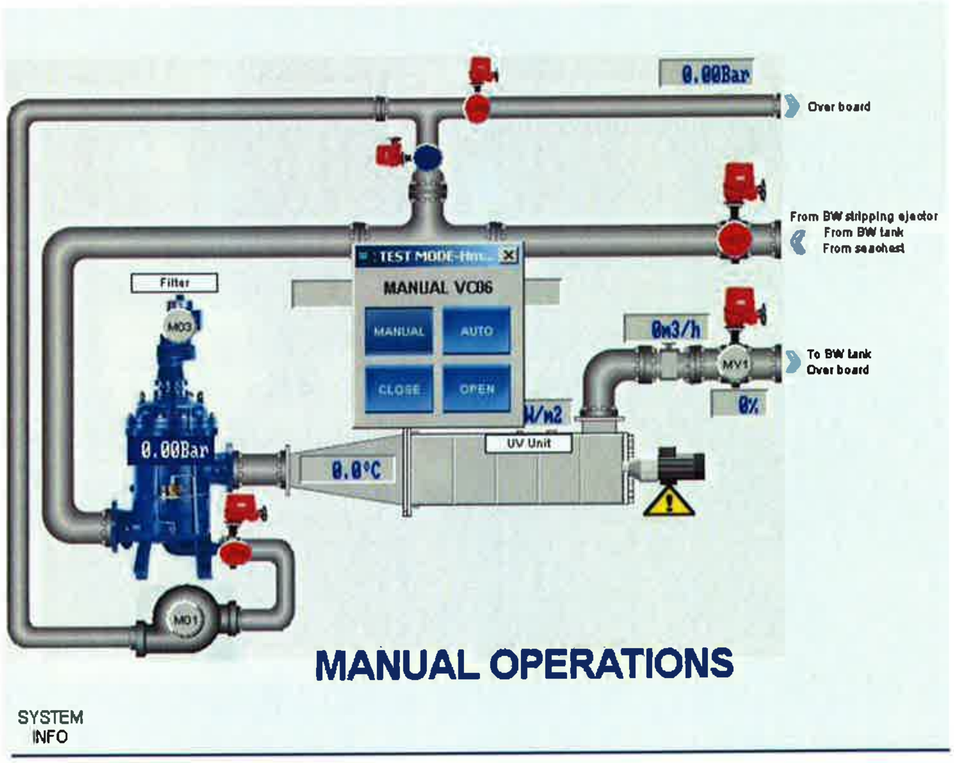
7.1.11 Manual Operation of valves

7.1.11.1 Start up of manual operation of valves

1) On the MAIN PAGE/UV Unit screen Press the circle containing the ID for the valve intended to be manually operated and a pop-up dialog box will appear.

2) Press the MANUAL button in the pop-up dialog box and the circle color changes to blue.
3) Press OPEN or CLOSE to open or close the valve.

NOTE: Max 3 pop-up boxes can be active simultaneously, but the number of valves can



7.2 Emergency shutdown and system by-pass procedures

Press Button Quick Stop for 3 seconds and the system will perform emergency shot down.

7.3 Requirements to achieve treatment objectives

Under preparation – to follow

7.4 Operating, safety, and emergency procedures

Under preparation – to follow

7.5 BWMS limitations, precautions and set points

Under preparation – to follow

7.6 Instructions on operation, calibration and zeroing of monitoring devices

Under preparation – to follow

7.7 Personnel requirements for the BWMS

Personnel requirements for the BWMS, including number and types of personnel needed, labor burden

7.8 Operator training or specialty certification requirements

None

8 Preventive and corrective maintenance requirements of the BWMS

8.1 Inspection and adjustment procedures

Under preparation – to follow

8.2 Troubleshooting procedures

Under preparation – to follow

8.3 Illustrated list of parts and spare parts

Under preparation – to follow

8.4 Recommended spare parts to have during installation and operation

Under preparation – to follow

8.5 Use of tools and test equipment in accordance with the maintenance procedures

Under preparation – to follow

8.6 Points of contact for technical assistance

Under preparation – to follow

9 Health and safety risks by contact with the BWMS

9.0 Health and safety Risks

9.0.1 Safety notifications

UV: Denotes immediate hazard with high risk which will cause death or serious physical injury if not avoided

DANGER: Denotes immediate hazard with high risk which will cause death or serious physical injury if not avoided.

WARNING: Denotes possible hazard with medium risk which may cause death or serious physical injury if not avoided.

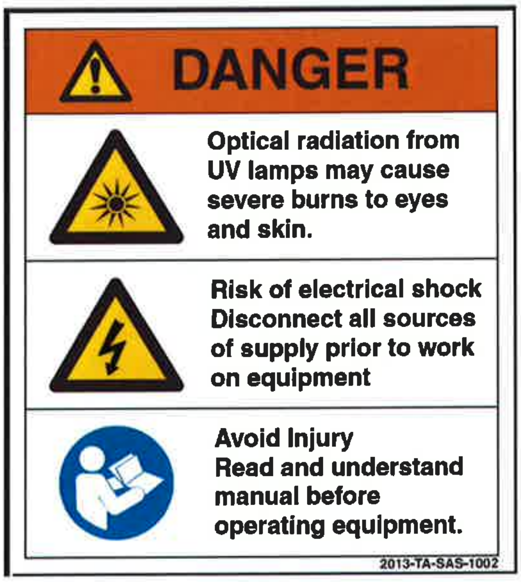
CAUTION: Denotes a hazard with low risk which could cause light or medium physical injury or material damages if not avoided.

NOTE: Denotes special user tips and other particularly useful or important information.

DISPOSAL Denotes special measures for environmental protection.

9.0.2 Safety signs placed on BWMS

Following safety sign is to be placed on Main control cabinet and on UV control cabinet



9.0.3 Health and safety Risks during installation

DANGER	**Optical radiation from UV lamps may cause severe burns to eyes and skin.** DO NOT Power up UV lamps when placed outside UV reactor DO NOT look inside reactor with powered up UV lamps
DANGER	**Risk of electrical shock, contact with live electrical parts,** Disconnect all sources of supply prior to work on equipment Only authorized personnel to work with electrical parts or systems
CAUTION	**Projection of high pressure fluids Water / Air** All sources of supply to be disconnected and all pipe systems to be depressurized and emptied prior to any work
CAUTION	**Contact with sharp edges/corners on components** Protective gloves to be worn during handling of the components. Protective glass to be worn during handling of the quartz sleves at UV lamps.
WARNING	**Falling objects** Work to be properly planned before adding components to new build systems or changing of existing systems. Protective shoes to be worn by operator
WARNING	**Gravity, stability risk of impact.** The equipment is designed to remain stable during all conditions. All parts to be thoroughly fixed to the foundation by bolting / welding.

9.0.4 Health and safety Risks during operation

DANGER	**Optical radiation from UV lamps may cause severe burns to eyes and skin.** DO NOT Power up UV lamps when placed outside UV reactor DO NOT look inside reactor with powered up UV lamps
DANGER	**Risk of electrical shock, contact with live electrical parts,** Disconnect all sources of supply prior to work on equipment Only authorized personnel to work with electrical parts or systems

9.0.5 Health and safety Risks during maintenance

DANGER	**Optical radiation from UV lamps may cause severe burns to eyes and skin.** DO NOT Power up UV lamps when placed outside UV reactor DO NOT look inside reactor with powered up UV lamps
DANGER	**Risk of electrical shock, contact with live electrical parts,** Disconnect all sources of supply prior to work on equipment Only authorized personnel to work with electrical parts or systems
CAUTION	**Projection of high pressure fluids Water / Air** All sources of supply to be disconnected and all pipe systems to be depressurized and emptied prior to any work
CAUTION	**Contact with sharp edges/corners on components** Protective gloves to be worn during handling of the components. Protective glass to be worn during handling of the quartz sleves at UV lamps.
WARNING	**Falling objects** Work to be properly planned before adding components to new build systems or changing of existing systems. Protective shoes to be worn by operator
WARNING	**Gravity, stability risk of impact.** The equipment is designed to remain stable during all conditions. All parts to be thoroughly fixed to the foundation by bolting / welding.

9.1 Storage, handling, and disposal of any hazardous wastes

No hazardous wastes are generated by the RayClean™ system.
UV-Lamps used in the UV-Unit contains amalgam and are to be stored, handled disposed according to MSDS for Amalgam lamps placed in Appendix xx

9.2 Health and safety certification/training requirements

The operation of RayClean™ system does not require any additional health and safety certification/training compared to the general requirements to health and safety certification/training on board.

9.3 Material safety data sheets

No hazardous materials or relevant chemicals are generated by or for the RayClean™ system.
UV-Lamps used in the UV-Unit contains amalgam and are to be handled according to MSDS for Amalgam lamps placed in Appendix xx
For the lubrication of the motors, pumps and valves please refer to the specific component instructions.

10 Submittal of new OMSM

This manual is not the final version – a revised version will be submitted soon.

If you have any comments or questions to this manual please contact Compliance Manager Jørgen Frahm by mail jfr@desmioceanguard.com

11 Appendices

Under preparation - …

Appendix A: User's manual for Mechanical Filter (xx pages)
Appendix B: Specification and data sheets for components used in UV Unit
UV Lamps
UV Lamp drivers
Appendix C: Users Manuals Sensors
Appendix D: Users Manuals Valves
Appendix E: Users Manuals Pumps
Appendix F: Safety Data Sheets

AMENDMENT No. 1

Test plan

Biological efficacy performance evaluation of the RayClean Ballast Water Management System in shipboard test. May 2013.

2013.06.22

Amendment comments

Temperature logging during shipment of samples

During transportation of samples the temperature will be logged and the data will be included in the final report.

Detailed information on shipment of samples

The transport time is crucial, and it will always be pursued to limit the time of transportation and to ship samples to the DHI environmental laboratory, Denmark in the quickest practical and possible way. Depending on the location and duration of a testing campaign it may take up to 3 days after de-ballast before samples arrive at the DHI environmental laboratory. After processing the samples on location, the samples will be stored cool and dark and temperature will be logged until shipment to the DHI environmental laboratory. Shortly before shipment the samples will be packed in cool boxes with temperature loggers. Survival of organisms in the size class ≥10 and< 50 µm during storage and transport will be represented by the enumeration of viable organisms in this size class in the control discharge water. According to MEPC.174(58) (IMO G8 guidelines) and U.S. Coast Guard Standards there are no specific requirements in relation to transport time of samples from shipboard testing.

Project organisation and personnel responsibilities

In Figure 2.1 DHI's project organisation. The Administration is Denmark, not Norway.

Analyses of organisms ≥10 and <50 µm

In section 7.2.3 of the test plan it is described that inverted microscopy enumeration for samples preserved with Lugol's solution will be applied to confirm that the validity criterion for the concentration of organisms ≥10 and <50 µm in the control discharge water is fulfilled. Enumeration of CMFDA/FDA stained organisms will be applied to confirm that the validity criterion for the concentration of organisms ≥10 and <50 µm in the control discharge water is fulfilled.

Time schedule

The first campaign (Campaign 1) with RayClean will include one test cycle. Campaign 1 is scheduled to be conducted between 23 and 26 June 2013 in Port Tangier, Morocco and Lisbon, Portugal.

Reason for Amendment

Detailed descriptions regarding approach for temperature logging and shipment of samples as requested by DNV. Correction of error in administration in figure 2.1. Adjusted methodology for analyses of organisms ≥10 and <50 µm described in section 7.2.3 and details on dates and locations for campaign 1 related to the time schedule in section 10 included.

Impact of Amendment

Temperature logging for storage and shipment of samples will be included in the final report. Enumeration of CMFDA/FDA stained organisms will be applied to confirm that the validity criterion for the concentration of organisms ≥10 and <50 µm in the control discharge water is fulfilled.

Preventive action

Not relevant.

Michael Andersen

Michael Andersen

____
Project manager

2013.06.22
Date

Copy to be sent to the client, the Certification Body and the DHI Quality Assurance Unit.

Attachment:

- DNV comments to the Test Plan

MEMO TO:	Ingrid Sigvaldsen	MEMO NO.:	
		FROM:	**DNV**
COPY:	Line Sverdrup	DATE:	**14.06.13**
	Jad Mouawad	PREP. BY:	Marte Rusten

Review of Quality Assurance Project Plan (QAPP) for biological efficacy performance evaluation of the "RAYCLEAN" Ballast Water Management System in shipboard test (DESMI Ocean Guard A/S)

The following documentation has been reviewed:

- ***Biological efficacy performance evaluation of the "RAYCLEAN" Ballast Water Management System in land-based test*** – test plan dated May 2013
- ***Biological efficacy performance evaluation of Ballast Water Management Systems – Quality Assurance Project Plan*** Version 2.2 dated March 2013

The DESMI Ocean Guard Ray Clean^{TM} BWTS is based on pre- and after treatment modules consisting of filtration in combination with UV. The objective of the project is to conduct a performance assessment of the BWMS with the aim to meet the testing requirements in IMO regulation D-2 and the U.S. Coast Guard Standards for living Organisms in Ships Ballast Water Discharged in U.S. Waters. In order to fulfil the US Coast Guards standard the BWMS must be tested according to the ETV protocol test plan during shipboard testing.

My impression is that the documents are well written and strategies for sampling, testing, data handling are described in sufficient detail and are in compliance with the requirements for shipboard testing.

My only concern is the time before analyses of the samples shipped from the Iberian Peninsula and would like DHI to include some detailed information on how samples are shipped back to the laboratory and the expected time before analyses. DNV normally requires that samples for the enumeration of organisms sized 10 µm – 50 µm samples are analysed within 24 hours after sampling. Any deviation from this requirement must be clearly stated and the documentation of survival of organisms during transportation must be provided.

DNV also requires that the temperature in the samples must be logged during transportation. This can be achieved by having separate bottles with temperature loggers to monitor temperature until the samples are processed at DHI. Please arrange for temperature logging during transport and report measurements in the final test report.

Yours sincerely

For DET NORSKE VERITAS AS

Marte Rusten

Marte Rusten, PhD
Senior consultant DNV

AMENDMENT No. 2

Test plan

Biological efficacy performance evaluation of the RayClean Ballast Water Management System in shipboard test. May 2013.

2013.10.29

Amendment comments

Time schedule
The second campaign (Campaign 2) with RayClean will include two test cycles. Campaign 2 is scheduled to be conducted between 1 and 3 November 2013 in Lisbon, Portugal and Algeciras, Spain.

Reason for Amendment
Planned amendment with details on dates and locations for campaign 2.

Impact of Amendment
None.

Preventive action
Not relevant.

f. Michael Andersen

____
Project manager

2013.10.29
Date

Copy to be sent to the client, the Certification Body and the DHI Quality Assurance Unit.

AMENDMENT No. 3

Test plan

Biological efficacy performance evaluation of the RayClean Ballast Water Management System in shipboard test. May 2013.

2014.01.22

Amendment comments

Time schedule
The third campaign (Campaign 3) with RayClean will include two test cycles. Campaign 3 is scheduled to be conducted between 25 and 30 January 2014 in Mindelo and Praia, Cape Verde.

Reason for Amendment
Planned amendment with details on dates and locations for campaign 3.

Impact of Amendment
None.

Preventive action
Not relevant.

Michael Andersen

Michael Andersen

____
Project manager

2014.01.22
Date

Copy to be sent to the client, the Certification Body and the DHI Quality Assurance Unit.

DET NORSKE VERITAS™

REPORT

SURVEY OF SHIPBOARD TEST NO.1 ON RAYCLEAN BALLAST WATER MANAGEMENT STSTEM

DESMI OCEAN GUARD A/S

REPORT NO./DNV REG NO.: TNANO386/QIWU/262.1-014477-J-32
REV, 0

MANAGING RISK

For: DESMI Ocean Guard A/S			
Account Ref.:			
Date of Current Issue:	2013-08-26	Project No.:PP085776/162	
Revision No.:	0	Organisation Unit:	Environmental Protection
DNV Reg. No.:		Report No.:	TNANO386/QIWU/262.1-014477-J-32

Summary:
The survey of shipboard test of RayClean-300 BWMS onboard THUROE MAERSK was conducted on 23th and 25th June 2013 by DNV surveyors as part of the Type Approval program. The test was the first of in total 5 test cycles. Based on observations during the survey, comments and recommendations were given for further testing of the BWMS. The final verification of the shipboard test will be done after the completion of the whole test trial, and based on evaluation of the test data and the logbook for the operations of RayClean during the trial.

Prepared by:	*Name and Position* Qinglan Wu	*Signature*
Verified by:	*Name and Position*	*Signature*
Approved by:	*Name and Position* Jad Mouawad Head of Section	*Signature*

☐ Unrestricted distribution (internal and external)	Keywords
☐ Unrestricted distribution within DNV	Ballast water treatment, BWMS, shipboard test
☒ Limited distribution within DNV after 3 years	
☐ No distribution (confidential)	
☐ Secret	

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
0	2013-08-27	First issue signed and verified	QIWU and RUSTEN		JADMO

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1 EXECUTIVE SUMMARY

DNV surveyors Jad Mouawad, Marte Rusten and Qinglan Wu attended the shipboard test of RayClean-300 BWMS onboard Thuroe Maersk on 23th and 25th June 2013. The survey was part of the Type Approval program for RayClean according to USCG 46 CFR 160.060, 33 and Guideline G8 of the IMO Ballast Water Management Convention.

The survey included:

1. Inspection of RayClean-300 BWMS test configuration onboard
2. Monitoring the operational performance of the BWMS during ballasting and de-ballasting and the bypassing of the BWMS system
3. Verifying that operation during testing of biological efficacy was conducted according to USCG guidelines

The tests of RayClean-300 BWMS during ballasting and de-ballasting operations were performed on 25 June 2013 when Thuroe Maersk was alongside at port Lisbon. This was the first test of in total 5 test cycles to be carried out on the same vessel over a period of 6 months.

The RayClean-300 BWMS was installed according to the Test Plan. The control system and the operation system worked normally during the tests.

Ballasting of control water was performed with a flow rate of ca. 300 m^3/h. For ballasting of treated water the flow rate was automatically reduced to 200-250 m3/h, due to high water turbidity and the flow regulation feature of RayClean BWMS. DNV recommend performing future ship board tests with a flow rate at the high end of the RayClean BWMS until receiving clear instructions from USCG.

All sampling procedures observed by DNV surveyors were according to QAPP, except for the inoculation of the MPN assay.

The ship officer performed ballasting control procedures.

Following the survey, DNV requires copies of all hand logs and a final report of the tests from DHI submitted to DNV.

The final verification of the shipboard test will be done after the completion of the whole test trial, and based on evaluation of the test data and the logbook for the operations of RayClean during the trial.

2 INTRODUCTION

The RayClean-300 BWMS is based on filter and UV disinfection technologies. The system treats ballast water through filtration and UV radiation, both during ballasting and de-ballasting. According to the technical manual by DESMI (DESMI Ocean Guard A/S, 2013-04-23), the system has a Treatment Rated Capacity of 300 m^3/h.

A special feature of the treatment system is that it can regulate the flow rate in turbid water to maintain the targeted UV-dose, and it can also dim UV light in clean water to save energy use. If the UV Intensity (UVI) is lower than 165 w/m^2, the flow rate will be reduced depending on water turbidity; if the UVI is higher than 200 w/m^2, the UV lamped will be dimmed, at a maximum of 50% of the original power.

3 MAIN PART OF REPORT

3.1 General Information

QAPP and Shipboard Test Plan were prepared by DHI (Gitte I. Petersen, 2013-05-15) and submitted to DNV. Both documents have been examined by DNV for compliance with IMO Guideline G8 and USCG Reg. 46 CFR Part 162 before testing. The "RayClean Operation Maintenance and Safety Manual" prepared by DESMI was approved with comments on 2013-06-19. DNV required the revision to be submitted to DNV as soon as possible.

The RayClean-300 BWMS has been installed onboard Thuroe Maersk since May 2013; and operated by the chief officer of the ship. However, the operation was stopped due to a leaking seal of the mechanical clean system. The leak was repaired by DESMI on 2013-06-22 before the test started.

Thuroe Maersk is a container ship of 16 982 Gross tonnage with 18 Ballast water tanks of in total ca. 8000 m3 ballast water capacity. The two ballast water tanks intended to be used for the test were tank no. B3SS (treated water) and B3SP (control water), each with a capacity of 512.8 m^3. The ballast water pump capacity for the test system was 300 m^3/h.

The ship's chief officer Ruben Peter Moreira was assigned to be responsible for operation of the ballasting and de-ballasting procedure. The crew was also requested to keep record of the operation, the location of ballasting and de-ballasting as well as weather condition during the whole test trial.

Camila Hedberg and Michael Andersen from DHI were responsible for sampling, storing and transporting of water samples to DHI laboratory, and analyzing part of the water samples on board.

Mark Kalhøj and Michael Claville from DESMI were also onboard, they did repair work and final check to ensure that the treatment system worked properly and the operational conditions were normal before the test started. DNV informed both DESMI and the chief officer that as soon as the test started DESMI personals should not be involved in any operation of the treatment system. During the whole test trial, the system should only be operated by the crew of the ship. Instructions for Operation of the RayClean BWMS during Type Approval Testing were prepared by DNV and sent to Thuroe Maersk crew and DESMI for information (enclosed with this report as Appendix 1).

A Letter of Readiness for shipboard testing of RayClean BWMS from DESMI was received on 25 June 2013 (enclosed as Appendix 2).

3.2 Parts of the assembly tested

The test system consists of the following main components:

- Filter unit: Boll & Kirch Filter (type 618.2 PN 10) with standard 30 µm filter
- UV cassette with 60 low pressure Philips 325 W lamps (type Philips TUV 325W XPT), an internal mechanical clean system, and UV intensity sensor (Type ZED 601-OE-I-037. 20mA = 500 W/m^2)
- UV control cabinet for the 60 lamp drivers (type Philips 913710054995 TUV 325W XPT Lamp Driver)
- Main Electrical cabinet for operating the system (HMI Omron type NS15-TX01B-V2 with CPU CJ2M-CPU31)
- Flow meter, type xxxx
- Filter back-flushing pump, type xxx

3.3 Survey of the BWMS test configuration

Before the start of the tests, the ballast water treatment system, the control systems and the sampling facilities were inspected and found in compliance with descriptions in Test Plan.

Arrangement of RayClean-300 BWMS

The filter unit, UV unit, flow meter and back-flushing pump were placed in a container installed close to the engine room (Figure 1a). The sampling facilities from DHI were also installed inside the container, temporarily for the tests. The RayClean BWMS system can be operated from the container as well as from a control panel in the ship's office at the deck.

The ballast pump and the ballast water by-pass valve were located in the engine room (Figure 1b). The ballast pump and the valves for the ballast tanks could be controlled from the ship's office, but not locally at the BWMS container. During the test, the operation of BWMS was performed in the control room and the sampling was performed locally at the BMWS container.

Fresh water from ship's technical water system was connected to the BWMS to flushing the BWMS system after each ballasting or de-ballasting to minimize corrosion risk. During the test, the system was flushed with fresh water after each operation to avoid cross contamination.

Currently, the DESMI BWMS control system is not integrated in the ship's Main Ballast Water Control System. The operation of BWMS has to be recorded manually by the crew of the ship.

a:

b:

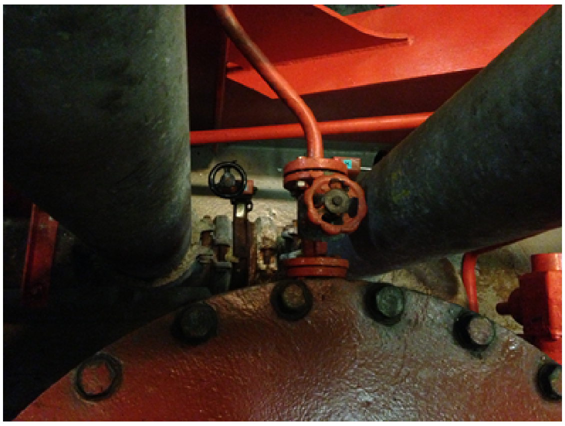


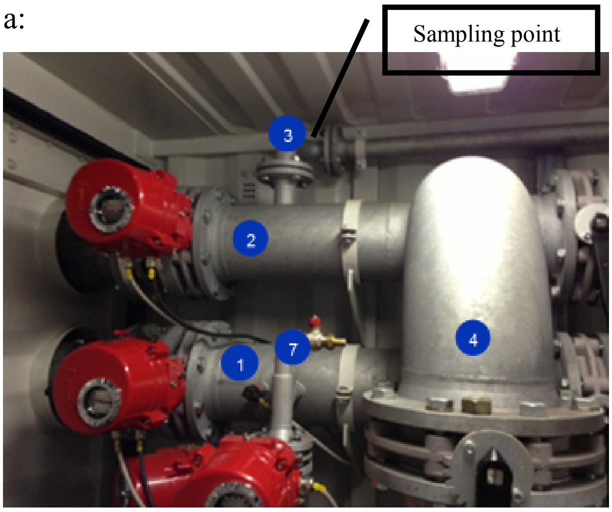
Figure 1a: The filter unit equipped with pressure sensor is connected to ballast water inlet pipe (on the left) and the UV unit (on right site) in a container; 1b: ballast water by-pass valve between in-let and out-let pipes in engine room.

Sampling point, pipes and valves to BWMS

The ship's ballast water system was connected to RayClean BWMS with two pipes, one at the inlet of the filter unit of the treatment system and one at the outlet of the UV unit of treatment system (Figure 2). The flow meter was installed in the outlet pipe after UV treatment unit. The sampling point located in the outlet pipe, as indicated in Fig 2a, was used for collecting both control water and treated water during ballasting and de-ballasting. From the sampling point, a ca. 8 meters long sampling line (3) was connected to the sampling facilities located in the same container.

To by-pass the treatment system, a connection was made between the inlet pipe and out-let pipes as illustrated in Figure 2 b. The two valves on the by-pass pipe were in open position when pumping sea water into control tanks, and closed when pumping sea water through the treatment system. By opening a small tube fixed on the side of the by-pass pipe it could be demonstrate whether or not water was inside the by-passes pipe.

a:



b:

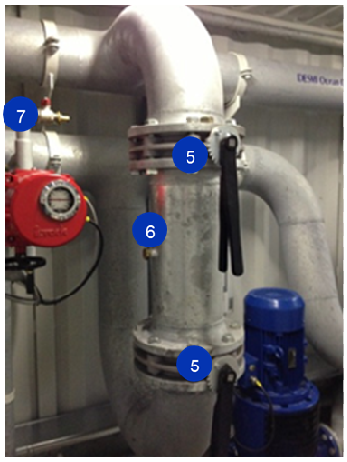


Figure 2a: (1) inlet pipe to the filter unit; (2) out-let from UV unit; (3) sampling point and sampling pipe to the sample collection port; (4) by-pass pipe with valves (5); (6) a tube with opening; (7) additional sampling point for collecting inlet water during BW treatment.

Sampling facilities and test laboratory on location

At the sample collection port, the sampling pipe was connected to a manifold with three outlets controlled by three flow meters, so that three parallel water samples could be collected simultaneously.

For collecting of organisms >50 µm, one sampling net was placed under each of the three outlets to collect three filtrate samples. For sampling of organisms < 50 µm and water quality samples, an extension of the manifold by flexible piping were used to collect water samples bottles.

A small test laboratory equipped with Zeiss Stemi 2000 microscope was located beside the ship office, which was used for sample preparation and counting of organisms onboard.

3.4 Observation during shipboard test

It was originally planned to perform the ballasting operation at port of Tangier and de-ballasting at the next port Lisbon. However, the test at Tangier had to be terminated as the ballast water pump could only run at 250 m^3/h, instead of 300 m^3/h. This was due to low water pressure at the pump inlet as a result of low draft of the ship at the port. It was then decided to test both ballasting and de-ballasting at the port in Lisbon where water is deeper.

Operation of BWMS

Ballasting of control water

The test started with pumping sea water into control tank No.3P at a flow rate of 300 m^3/h. The treatment system was bypassed by opening the by-pass valves. During ballasting, three sets of water samples were taken at an interval of 20 minutes; samples for organisms >50 µm were collected continuously through nets. Approximately 300 m^3 water was pumped into the control tank.

Sea water at the port looked quit turbid. Based on onboard microscopic counting, the organisms >50 µm in inlet water was estimated as >10^5 cell/m^3.

Flushing of pipes with treated water

The RayClean BWMS was started and warmed up, the by-pass valves (5) were closed, and treated water was pumped through the piping system for cleaning purpose.

Ballasting of treated water

To test the treatment system during ballasting, sea water was pumped through the BW treatment system into tank no. 3S. Different control parameters could be monitored on the display of control panels in the container, as well as in the ship office. The UV intensity was 123 w/m^2, which was below the set value of 165 w/m^2 for starting the flow regulation system. The flow rate was reduced and varied in a range between 200 and 250 m^3/h. The back flushing of filter was automatically starting and stopping when the pressure difference across the filter raising to 0.5 bar or falling back to 0.35 bar. The water temperature was 16.3 °C and water pressure in piping system was between 1.5 and 2.7 bar.

De-Ballasting of control water and treated water

De-ballasting of control water from Tank no. 3P and subsequent de-ballasting of treated water from tank No. 3S were performed after a holding time of ca. 2 hours. Water samples were collected.

DNV surveyors were not onboard during the de-ballasting operations. Following the survey, DNV requires copies of all hand logs and a final report of the tests from DHI submitted to DNV.

4 COMMENTS AND RECOMMENDATIONS

The shipboard test was evaluated for compliance with the requirements set out in USCG §162.060-28 and IMO G8, Annex Part 2.2. The following comments and recommendations are given:

- The “Operational and Maintenance and Safety Manual” was not yet finalized at the time when shipboard test started. Information on a) maintenances parameters and maintenance requirements and b) all instrument calibration methods and frequency of calibration need to be included in the OMSM and submitted to DNV as soon as possible (ref. §162.060-28, c-(2) and i-(9)). The crew member operating the BWMS should also be informed.

- Due to the flow regulation feature of RayClean BWMS and the high turbidity of the source water, the maximum flow rate of 300 m^3/h was not achieved for the first test. DNV has discussed the issue with USCG, but no conclusion was made so far. DNV recommend using the flow rate representative of the upper end of the TRC wherever possible until receiving final decision from USCG (ref. §162.060-28, e-(1)).

- To meet the requirements regarding geographic and seasonal variability conditions (ref. §162.060-28, e-(2)), DNV recommend conducting further tests at Bissau and Morocco, in addition to Lisbon. Further investigation is needed to ensure that the recommended locations meet the USCG requirements on source water and port facilities (ref. §162.060-28 e-(2)-i+ ii and e-(3)).

- The final verification of the shipboard test will be done after completion of the whole test trial, and based on evaluation of DHI test report and documentation and logbook for the operations of RayClean during the trial ref (§162.060-28, i)
- Additional comments may be found in the Memo; survey report for 1st shipboard test of DESMI Ocean Guard A/S RayClean BWMS

In addition, it was noticed that the leaking seal in cleaning mechanism was discovered by the crew when they observed water in the container, no alarm was given by the BWMS. Technical measures to avoid flooding should be considered, and any improvement/modification in RayClean BWMS should be reported and reflected in the OMSM.

5 REFERENCES

/1/ Biological efficacy performance evaluation of the RayClean Ballast Water Management System in shipboard test-Test Plan, (2013 May), Rasmus Folsø, DHI Agern Allè 5, DK-2970 Hørsholm, Denmark.

/2/ Operation, Maintenance and Safety Manual, RayClean BWMS (2013-04-23), DESMI Ocean Guard A/S, Lufthavnsvej 12, DK-9400 Nørresundby, Denmark.

6 APPENDIX

6.1 Appendix 1: Instructions for Operation of the RayClean BWMS during Type Approval Testing,

6.2 Appendix 2: Letter of Readiness for shipboard testing of RayClean BWMS

Det Norske Veritas:

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APPENDIX 2

Data logging from the biological efficacy testing with RayClean

Table A.2.1.1 Data logging treated water, shipboard test cycle No. 1

Subject	Data
Treatment system	RayClean
Manufacturer specified parameters (e.g. number of treatment reactors/units, filter model, filter mesh size, etc.)	1 UV unit: Max. TRC 300 m^3/h 60 low pressure UV lamps: DESMI Ocean Guard item No. 716433 Filter: Boll&Kirch type 6.18.2 BWT DN 250; 30-µm mesh candles
Salinity (PSU)	34
Ballast tank No.	3 port side
Test cycle No.	1
Date and time ballast start	2013.06.25 18:12 (local time, GMT+0)
Date and time ballast stop	2013.06.25 19:33 (local time, GMT+0)
Location for ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 41.9 'N; 009^0 09.8 'W
Treated volume during ballast	285 m^3
Flow rate during ballast (calculated)	211 m^3/h
Power consumption during ballast	28 kWh
UV intensity during ballast	88-137 W/m^2
Date and time de-ballast start	2013.06.26 00:24 and 01:00 (local time, GMT+0)
Date and time de-ballast stop	2013.06.26 00:45 and 01:22 (local time, GMT +0)
Location for de-ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 41.9 'N; 009^0 09.8 'W
Treated volume during de-ballast	171 m^3 (85 and 86 m^3)
Flow rate during de-ballast (calculated)	239 m^3/h
Power consumption during de-ballast	17 kWh (8.9 and 7.9 kWh)
UV intensity during de-ballast	128-134 W/m^2
Weather conditions during test	Wind 5 knots; NW; wave height 0 m
General comments/operational issues	Deballast operation was interrupted for 15 min due to water in an electrical socket caused by a leaking DHI sampling unit. Failure on lamp No. 25 in the RayClean BWMS registered. Lamp reset function was activated, which solved the problem.

Table A.2.1.2 Data logging control water, shipboard test cycle No. 1

Subject	Data
Salinity (PSU)	34
Ballast tank No.	3 starboard side
Date and time ballast start	2013.06.25 15:45 (local time, GMT+0)
Date and time ballast stop	2013.06.25 16:50 (local time, GMT+0)
Location for ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 41.9 ‘N; 009^0 09.8 ‘W
Volume during ballast*	273 m^3
Flow rate during ballast (calculated)*	252 m^3/h
Date and time de-ballast start	2013.06.25 21:24 (local time, GMT+0)
Date and time de-ballast stop	2013.06.25 22:01 (local time, GMT+0)
Location for de-ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 41.9 ‘N; 009^0 09.8 ‘W
Volume during de-ballast*	137 m^3
Flow rate during de-ballast (calculated)*	222 m^3/h
General comments/operational issues	RayClean installation bypassed during ballast operation of control water.

* Volume recording and associated flow rate based on the vessel’s ballast tank level gauging system. Recordings may be uncertain as a result of heeling of the vessel.

Table A.2.1.3 Onsite measurements, shipboard test cycle No. 1 (standard deviations in parentheses)

Water type	Dissolved oxygen (mg/L)	pH	Salinity (PSU)	Temperature (°C)	Turbidity (NTU)
Inlet control	6.5 (±0.15)	7.9 (±0.02)	34 (±0.60)	17 (±0.43)	28 (±0.00)
Inlet BWMS	6.4 (±0.27)	7.9 (±0.02)	34 (±1.3)	17 (±0.93)	13 (±4.5)
Control discharge	6.5 (±0.14)	7.9 (±0.00)	34 (±0.26)	17 (±0.26)	18 (±0.00)
Treated discharge	6.5 (±0.17)	7.9 (±0.01)	34 (±0.65)	18 (±0.24)	10 (±0.58)

PSU Practical salinity units
NTU Nephelometric turbidity units

Table A.2.2.1 Data logging treated water, shipboard test cycle No. 2

Subject	Data
Treatment system	RayClean
Manufacturer specified parameters (e.g. number of treatment reactors/units, filter model, filter mesh size, etc.)	1 UV unit: Max. TRC 300 m^3/h 60 low pressure UV lamps: DESMI Ocean Guard item No. 716433 Filter: Boll&Kirch type 6.18.2 BWT DN 250; 30-µm mesh candles
Salinity (PSU)	29-32
Ballast tank No.	3 Port side
Test cycle No.	2
Date and time ballast start	2013.11.01 16:42 (local time, GMT+0)
Date and time ballast stop	2013.11.01 19:23 (local time, GMT+0)
Location for ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 42 'N; 009^0 10 'W
Treated volume during ballast	523 m^3
Flow rate during ballast (calculated)	195 m^3/h
Power consumption during ballast	52 kWh
UV intensity during ballast	40-205 W/m^2
Date and time de-ballast start	2013.11.03 09:04 (local time, GMT+0)
Date and time de-ballast stop	2013.11.03 09:52 (local time, GMT+0)
Location for de-ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 42 'N; 009^0 10 'W
Treated volume during de-ballast	227 m^3
Flow rate during de-ballast (calculated)	284 m^3/h
Power consumption during de-ballast	14 kWh
UV intensity during de-ballast	200-282 W/m^2
Weather conditions during test	Wind 1-2 m/s; N.b.E; wave height 0 m
General comments/operational issues	Before initiating the test cycle, the Boll&Kirch filter was checked by sea-to-sea operation, which showed that the differential pressure was too high. Therefore, DESMI Ocean Guard staff manually made the filter backwash in order to clean the filter elements. During the ballast operation, a "low UV" alarm occurred as the UV intensity dropped below the system limit of 55 W/m^2. Nevertheless, ballast operation was continued. The UV intensity was below 55 W/m^2 for approx. 30 min.

Table A.2.2.2 Onsite measurements, shipboard test cycle No. 2 (standard deviations in parentheses)

Water type	Dissolved oxygen (mg/L)	pH	Salinity (PSU)	Temperature (°C)	Turbidity (NTU)
Inlet control	5.7 (±0.10)	7.4 (±0.01)	29 (±0.18)	19 (±0.01)	8.7 (±1.2)*
Inlet BWMS	6.1 (±0.39)	7.4 (±0.02)	31 (±0.97)	19 (±0.23)	56 (±33)*
Control discharge	6.3 (±0.64)	7.4 (±0.01)	30 (±0.35)	19 (±0.49)	20 (±23)
Treated discharge	5.6 (±0.13)	7.4 (±0.01)	31 (±0.18)	19 (±0.05)	5.0 (±0.00)

PSU Practical salinity units
NTU Nephelometric turbidity units
* The turbidity in the inlet water varied during ballast operations as a result of passing vessels stirring up sediment

Table A.2.3.1 Data logging treated water, shipboard test cycle No. 3

Subject	Data
Treatment system	RayClean
Manufacturer specified parameters (e.g. number of treatment reactors/units, filter model, filter mesh size, etc.)	1 UV unit: Max. TRC 300 m^3/h 60 low pressure UV lamps: DESMI Ocean Guard item No. 716433 Filter: Boll&Kirch type 6.18.2 BWT DN 250; 30-µm mesh candles
Salinity (PSU)	29-32
Ballast tank No.	3 starboard side
Test cycle No.	3
Date and time ballast start	2013.11.01 21:33 (local time, GMT+0)
Date and time ballast stop	2013.11.01 23:23 (local time, GMT+0)
Location for ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 42 'N; 009^0 10 'W
Treated volume during ballast	405 m^3
Flow rate during ballast (calculated)	221 m^3/h
Power consumption during ballast	36 kWh
UV intensity during ballast	61-230 W/m^2
Date and time de-ballast start	2013.11.03 14:01 (local time, GMT+0)
Date and time de-ballast stop	2013.11.03 14:47 (local time, GMT+0)
Location for de-ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 42 'N; 009^0 10 'W
Treated volume during de-ballast	223 m^3
Flow rate during de-ballast (calculated)	291 m^3/h
Power consumption during de-ballast	15 kWh
UV intensity during de-ballast	156-208 W/m^2
Weather conditions during test	Wind 1-2 m/s; N.b.E; wave height 0 m
General comments/operational issues	-

Table A.2.3.2 Onsite measurements, shipboard test cycle No. 3 (standard deviations in parentheses)

Water type	Dissolved oxygen (mg/L)	pH	Salinity (PSU)	Temperature (°C)	Turbidity (NTU)
Inlet control	5.7 (±0.10)	7.4 (±0.01)	29 (±0.18)	19 (±0.01)	8.7 (±1.2)*
Inlet BWMS	6.4 (±0.32)	7.4 (±0.02)	30 (±1.1)	19 (±0.08)	38 (±17)*
Control discharge	6.3 (±0.64)	7.4 (±0.01)	30 (±0.35)	19 (±0.49)	20 (±23)
Treated discharge	5.7 (±0.12)	7.4 (±0.00)	31 (±0.11)	19 (±0.00)	7.3 (±3.2)

PSU Practical salinity units
NTU Nephelometric turbidity units
* The turbidity in the inlet water varied during ballast operations as a result of passing vessels stirring up sediment

Table A.2.3.3 Data logging control water, shipboard test cycle No. 2 and 3

Subject	Data
Salinity (PSU)	29
Ballast tank No.	4 port side
Date and time ballast start	2013.11.01 20:01 (local time, GMT+0)
Date and time ballast stop	2013.11.01 21:12 (local time, GMT+0)
Location for ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 42 ‘N; 009^0 10 ‘W
Volume during ballast*	373 m^3
Flow rate during ballast (calculated)*	315 m^3/h
Date and time de-ballast start	2013.11.03 12:40 (local time, GMT+0)
Date and time de-ballast stop	2013.11.03 13:26 (local time, GMT+0)
Location for de-ballast (latitude/longitude)	Alcântara Container Terminal; Port of Lisbon (PT) Coordinates: 38^0 42 ‘N; 009^0 10 ‘W
Volume during de-ballast*	201 m^3
Flow rate during de-ballast (calculated)*	262 m^3/h
General comments/operational issues	RayClean installation bypassed during ballast operation of control water

* Volume recording and associated flow rate based on the ballast tank level gauging system of the vessel. Recordings may be uncertain as a result of heeling of the vessel.

Table A.2.4.1 Data logging treated water, shipboard test cycle No. 4

Subject	Data
Treatment system	RayClean
Manufacturer specified parameters (e.g. number of treatment reactors/units, filter model, filter mesh size, etc.)	1 UV unit: Max. TRC 300 m^3/h 60 low pressure UV lamps: DESMI Ocean Guard item No. 716433 Filter: Boll&Kirch type 6.18.2 BWT DN 250; 30-µm mesh candles
Salinity (PSU)	37
Ballast tank No.	3 port side
Test cycle No.	4
Date and time ballast start	2014.01.27 16:49 (local time, GMT-1)
Date and time ballast stop	2014.01.27 18:24 (local time, GMT-1)
Location for ballast (latitude/longitude)	Porto Grande; Mindelo; Cape Verde Coordinates: 16^0 53.3 'N; 24^0 59.9 'W
Weather conditions during ballast	Wind 8-9 m/s; N.b.E; wave height 0.5 m
Treated volume during ballast	465 m^3
Flow rate during ballast (calculated)	294 m^3/h
Power consumption during ballast	30 kWh
UV intensity during ballast	500 W/m^2
Date and time de-ballast start	2014.01.29 15:58 (local time, GMT-1)
Date and time de-ballast stop	2014.01.29 16:39 (local time, GMT-1)
Location for de-ballast (latitude/longitude)	Porto da Praia; Praia; Cape Verde Coordinates: 14^0 54.5 'N; 23^0 30.0 'W
Weather conditions during de-ballast	Wind 4-6 m/s; N.b.E; wave height 0 m
Treated volume during de-ballast	186 m^3
Flow rate during de-ballast (calculated)	272 m^3/h
Power consumption during de-ballast	13 kWh
UV intensity during de-ballast	500 W/m^2
General comments/operational issues	During BWMS start-up for the ballast operation, an alarm occurred: "Fault lamp driver in UV unit#1; Lamp fault No. 28". The fault was caused by water in the UV lamp quartz sleeve due to a leaking gasket. Lamp No. 28 was replaced and the BWMS was restarted. Weather conditions during voyage from Mindelo to Praia, Cape Verde: 12-20 m/s N.b.E; wave height 2 m.

Table A.2.4.2 Data logging control water, shipboard test cycle No. 4

Subject	Data
Salinity (PSU)	37
Ballast tank No.	3 starboard side
Date and time ballast start	2014.01.27 14:26 (local time, GMT-1)
Date and time ballast stop	2014.01.27 15:50 (local time, GMT-1)
Location for ballast (latitude/longitude)	Porto Grande; Mindelo; Cape Verde Coordinates: 16^0 53.3 'N; 24^0 59.9 'W
Volume during ballast*	400 m^3
Flow rate during ballast (calculated)*	286 m^3/h
Date and time de-ballast start	2014.01.29 16:52 (local time, GMT-1)
Date and time de-ballast stop	2014.01.29 17:12 (local time, GMT-1)
Location for de-ballast (latitude/longitude)	Porto da Praia; Praia; Cape Verde Coordinates: 14^0 54.5 'N; 23^0 30.0 'W
Volume during de-ballast*	127 m^3
Flow rate during de-ballast (calculated)*	381 m^3/h
General comments/operational issues	RayClean installation bypassed during ballast operation of control water.

* Volume recording and associated flow rate based on the ballast tank level gauging system of the vessel. Recordings may be uncertain as a result of heeling of the vessel.

Table A.2.4.3 Onsite measurements, shipboard test cycle No. 4 (standard deviations in parentheses)

Water type	Dissolved oxygen (mg/L)	pH	Salinity (PSU)	Temperature (°C)	Turbidity (NTU)
Inlet control	6.2 (±0.06)	8.1 (±0.01)	37 (±0.06)	22 (±0.04)	5.3 (±0.38)
Inlet BWMS	5.9 (±0.54)	8.2 (±0.01)	37 (±0.02)	22 (±0.04)	4.9 (±0.38)
Control discharge	6.5 (±0.02)	8.1 (±0.00)	37 (±0.01)	23 (±0.00)	3.3 (±0.58)
Treated discharge	6.5 (±0.02)	8.1 (±0.04)	37 (±0.00)	23 (±0.00)	4.0 (±0.00)

PSU Practical salinity units
NTU Nephelometric turbidity units

Table A.2.5.1 Data logging treated water, shipboard test cycle No. 5

Subject	Data
Treatment system	RayClean
Manufacturer specified parameters (e.g. number of treatment reactors/units, filter model, filter mesh size, etc.)	1 UV unit: Max. TRC 300 m^3/h 60 low pressure UV lamps: DESMI Ocean Guard item No. 716433 Filter: Boll&Kirch type 6.18.2 BWT DN 250; 30-μm mesh candles
Salinity (PSU)	37
Ballast tank No.	8 port side
Test cycle No.	5
Date and time ballast start	2014.01.27 21:01 (local time, GMT-1)
Date and time ballast stop	2014.01.27 22:18 (local time, GMT-1)
Location for ballast (latitude/longitude)	Porto Grande; Mindelo; Cape Verde Coordinates: 16^0 53.3 'N; 24^0 59.9 'W
Weather conditions during ballast	Wind 8-9 m/s; N.b.E; wave height 0.5 m
Treated volume during ballast	377 m^3
Flow rate during ballast (calculated)	294 m^3/h
Power consumption during ballast	24 kWh
UV intensity during ballast	500 W/m^2
Date and time de-ballast start	2014.01.29 20:53 (local time, GMT-1)
Date and time de-ballast stop	2014.01.29 21:36 (local time, GMT-1)
Location for de-ballast (latitude/longitude)	Porto da Praia; Praia; Cape Verde Coordinates: 14^0 54.5 'N; 23^0 30.0 'W
Weather conditions	Wind 4-6 m/s; N.b.E; wave height 0 m
Treated volume during de-ballast	180 m^3
Flow rate during de-ballast (calculated)	251 m^3/h
Power consumption during de-ballast	14 kWh
UV intensity during de-ballast	500 W/m^2
General comments/operational issues	During BWMS start-up for the de-ballast operation, an alarm occurred: “Fault lamp driver in UV unit#1; Lamp fault No. 29”. The UV lamps were reset and hereafter no more alarms occurred. Weather conditions during voyage from Mindelo to Praia, Cape Verde:12-20 m/s N.b.E; wave height 2 m

Table A.2.5.2 Data logging control water, shipboard test cycle No. 5

Subject	Data
Salinity (PSU)	37
Ballast tank No.	8 starboard side
Date and time ballast start	2014.01.27 19:30 (local time, GMT-1)
Date and time ballast stop	2014.01.27 20:56 (local time, GMT-1)
Location for ballast (coordinates)	Porto Grande; Mindelo; Cape Verde Coordinates: 16^0 53.3 'N; 24^0 59.9 'W
Volume during ballast (approx.)*	391 m^3
Flow rate during ballast (calculated)*	273 m^3/h
Date and time de-ballast start	2014.01.29 22:10 (local time, GMT-1)
Date and time de-ballast stop	2014.01.29 22:31 (local time, GMT-1)
Location for de-ballast (coordinates)	Porto da Praia; Praia; Cape Verde Coordinates: 14^0 54.5 'N; 23^0 30.0 'W
Volume during de-ballast*	146 m^3
Flow rate during de-ballast (calculated)*	417 m^3/h
General comments/operational issues	RayClean installation bypassed during ballast operation of control water.

* Volume recording and associated flow rate based on the vessel's ballast tank level gauging system. Recordings may be uncertain as a result of heeling of the vessel.

Table A.2.5.3 Onsite measurements, shipboard test cycle No. 5 (standard deviations in parentheses)

Water type	Dissolved oxygen (mg/L)	pH	Salinity (PSU)	Temperature (°C)	Turbidity (NTU)
Inlet control	6.1 (±0.07)	8.2 (±0.00)	37 (±0.01)	22 (±0.01)	4.3 (±0.38)
Inlet BWMS	6.1 (±0.29)	8.2 (±0.01)	37 (±0.01)	22 (±0.00)	4.0 (±0.00)
Control discharge	6.8 (±0.02)	8.1 (±0.00)	37 (±0.01)	23 (±0.00)	3.0 (±0.00)
Treated discharge	6.5 (±0.07)	8.1 (±0.00)	37 (±0.02)	23 (±0.00)	3.3 (±0.58)

PSU Practical salinity units
NTU Nephelometric turbidity units

APPENDIX 3

DESMI Ocean Guard shipboard testing documentation

MAERSK

Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: Thurø Mærsk | **Ballast Tank No. 3 PORT SIDE TANK** | **Tank Volume m^3. 526.0**

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m^3	In / Out	Tank Quantity m^3	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
18/11 - 12	0650 - 1400	TANGIER MED		1,028	435	IN	435				4/o
27/11-12	0920-0940	ALGECIRAS		1,028	210	OUT	225				3/o Narum
02/12-12	2230-2300	MINDELO		1,026	125	OUT	100				3/o Narum
05/12-12	2305-2330	PRAIA		1.027	50	OUT	50				4/o
~~08/12/12~~	~~1530-1630~~	~~BISSAU~~									2/o
08/12/12	2000-2030	BISSAU.		1015	50	IN	50				3/o Narum
31/12/12	2100-2120	NOUADHIBOU		1028	50	OUT	0			MTY	3/o Narum
19/12-2012	2000-2045	TANGIER MED		1028	250	IN	250				4/o
31/12-2012	0520-0630	ALGECIRAS		1030	250	OUT	0			MTY	3/o Narum
21-01-2013	00^{15}-06^{00}	TANGIER-MED	18	1.028	526	IN	526			FULL	3/o KGN
31-01-2013	02^{20}-04^{00}	LISBON		1.028	526	OUT	0			MTY	2/o S.L.
12-02-2013	19^{00}-22^{30}	PRAIA		1026	526	IN	526			FULL	3/o KGN
05-03-2013	10^{00}-13^{25}	LISBON		1026	526	OUT	0			MTY	3/o KGN
07 04 2013	1700-2500	TANGER			526	IN	526			Full	3/o C. Thygesen
10 04 2013	1700-2000	LISBON		1010	526	OUT	0			MTY	3/o C. Thygesen
01/6-2013	0410-0530	MINDELO		1026	450	IN	450				2/o
05/06/2013	0500-0630	PRAIA		1025	450	OUT	0			MTY	3/o
22/06-13	0800-1000	32°25.6N 009°33.9W		1025	250	IN	250			MID OCEAN GRAVITY	4/o
22/06-13	1000-1100	32°52.6N 009°06.6W		1025	250	OUT	0			MTY PUMP	4/o
22/06-13	1100-1400	33°19.5N 008°38.3W		1025	500	IN	500			MID OCEAN GRAV/PUMP	4/o
22/06-13	1400-1600	33°37.3N 008°20.6W		1025	500	OUT	0			MTY PUMP	4/o
22/06-13	1600-1800	33°54.7N 008°01.5W		1029	250	IN	250			MID OCEAN GRAVITY	4/o
22/06-13	1800-2200	34°31.3N 007°23.3W		1025	250	OUT	0			MTY PUMP	4/o
24/6 - 13	0405-0575	TANGIER		1028	500	IN	500			MTY	2/o
~~20/06-13~~	~~1530-1430~~	~~ALGICERAS~~		~~1023~~	~~200~~	~~OUT~~	~~300~~			~~MTY~~	3/o
30/06-13	1500-1030	ALGICERAS		1028	500	OUT	0			MTY	3/o
4/8-2013	1530-1730	LISBON		1027	215	IN	215			GRAVITY + PUMP	2/o
10-08-2013	0950-1020	LEIXOES		1017	55	IN	270			PUMP IN BWTS	3/o
13 08 2013	06:00 0730	ALGICERAS		1017	270	OUT	0			MTY BWTS	3/o
20 08 2013	2335-2353	PRAIA		1024	100	IN	100			PUMPIN BWTS	3/o
16/9-2013	0000-0200	TANGIER		1026	420	IN	520			FULL BWTS	3/o

Master: Capt. Jan Christensen   Signature: ________   Date: ________

MAERSK

Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: Thurø Mærsk **Ballast Tank No. 3 PORT SIDE TANK** **Tank Volume m^3. 526.0**

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m^3	In / Out	Tank Quantity m^3	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
20/9-13	18-2100	LISBON		1026	520	OUT	0			MTY BWTS	3/o
22/9 13	1125-1200	LEIXOES		1025	130	IN	130			BY Gravity	3/o
25/9-2013	0920-[illegible]	ALGECIRAS		1027	130	out	0			Mty	2/o
28/10-13	[illegible]	TANGIER		1.024	526	IN	526			FULL BWTS	2/o
30/10-13	1048-1530	LEIXOES		1.010	526	OUT	0			MTY BWTS	2/o
04/11-13	1200-1240	LISBON		1.019	200	IN	200			GRAVITY	2/o
07/11-13	2340-0025	ALGECIRAS		1.026	200	OUT	0				2/o
24/12-13	1235-1415	PRAIA		1.023	200	IN	200			BWTS	2/o
09/01-14	0054-0145	NOUADHIBOU		1.025	200	OUT	0			MTY BWTS	2/o
12/01-14	17:48-2015	TANGIER	+17	1.025	300	IN	300			Grav.	C/O
19/01-14	15:50-1700	ALGECIRAS	+16	1.025	175	OUT	125				C/O
21/01-14	1000-1100	32°21'7N-010°03'3W	+19	1.025	125	OUT	0			MTY	C/O
27/01-14	16:00-2000	MINDELO	+24	1.025	400	IN	400			BWTS	C/O
29/01-14	1600-2300	PRAIA	+26	1.025	400	OUT	0			MTY -> BWTS	C/O
23/03-14	1500-1900	TANGIER		1.025	520	IN	520			BY PUMP	3/o
25/03-14	1545-1745	LISBON		1.025	520	OUT	0			BY PUMP EMPTY	2/o

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Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: THURØ MAERSK. **Ballast Tank No** DB-3-STBD **Tank Volume** m^3. 512,8 m^3

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m^3	In / Out	Tank Quantity m^3	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
19/12-2012	2000 - 2045	TANGIER MED		1028	250	IN	250				9/0
31/12-2012	0520-0630	ALGECIRAS		1030	250	OUT	0			MTY	3/0
21-01-2013	00^15 - 06^00	TANGIER MED	18	1028	526	IN	526			FULL	3/0 KGN
31-01-2013	02^20 - 04^00	LISBON		1.028	526	OUT	0			MTY	2/0
12-02-2013	19^00 - 22^30	PRAIA		1026	526	IN	526			FULL	3/0 KGN
05-03-2013	6^00 - 13^30	LISBON		1026	526	OUT	0			MTY	3/0 KGN
07 04 2013	1700-2300	TANGER			526	IN	526			Full	3/0 C. Thyregaard
09 04 2013	1700-2050	LISBON		1010	526	OUT	0			MTY	3/0 C. Thyregaard
22/06-13	0800-1000	32°25.6N 009°33.9W		1025	250	IN	250			MID OCEAN GRAVITY	C/0
22/06-13	1000-1100	32°52.6N 009°06.6W		1025	250	OUT	0			MTY PUMP	C/0
22/06-13	1100-1400	33°19.5N 008°38.3W		1025	500	IN	500			MID OCEAN GRAV / PUMP	C/0
22/06-13	1400-1600	33°37.3N 008°20.6W		1025	500	OUT	0			MTY PUMP	C/0
22/06-13	1600-1800	33°54.7N 008°01.5W		1025	250	IN	250			MID OCEAN GRAVITY	C/0
22/06-13	1800-2200	34°31.3N 007°23.3W		1025	250	OUT	0			MTY PUMP	C/0
24/6-13	0205-0535	TANGIER		1028	500	IN	500				C/0
27/06-13	15.00-17.30	LEIXOES		1025	500	OUT	0			BY EJEC. MTY	C/0
16/9-2013	0000-0200	TANGIER		1026	520	IN	520			FULL-BWTS	2/0
20/9-2013	1800-2100	LISBON		1026	520	OUT	0			MTY-BWTS	3/0
28/10-2013	PORTSTAY	TANGIER		10.24	524	IN	524			FUL-BWTS	2/0
30/10 13	1040-1530	LEIXOES		1024	524	OUT	0			MTY-BWTS	2/0
05/11-2013	03:00-03:50	TANGIER		1.024	100	IN	100			By Gravity	C/0
12/12-2013	1600-16:30	LEIXOES		1.024	100	OUT	0			MTY	C/0
12/01-14	1748-2000	TANGIER	17	1.025	300	IN	300			Grav.	C/0
~~14/01-14~~	~~1120-1300~~	~~LISBON~~		~~1.014~~	~~300~~	~~OUT~~	~~0~~			~~MTY~~	~~2/0~~
19/01-2014	1245-1426	ALGECIRAS	16	1.025	300	OUT	0			MTY	C/0
27/01-2014	1600-2000	MINDELO	24	1.025	400	IN	400			BWTS	C/0
29/01-2014	1600-23:00	PRAIA	26	1.025	400	OUT	0			MTY — BWTS	C/0
23/03-2014	1500-1900	TANGIER		1.025	520	IN	520			BY PUMP	3/0
25/03-14	1545-1745	LISBON		1.025	520	OUT	0			BY PUMP EMPTY	

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Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: Thurø Mærsk | **Ballast Tank No. 4 PORT SIDE TANK** | **Tank Volume m^3. 733.0**

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m^3	In./ Out	Tank Quantity m^3	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
11-01-2013	20³⁰ - 21¹⁰	BISSAU		1.028	120	OUT	0			MTY	3/0 KGN
20-01-2013	21⁴⁰ - 00¹⁰	TANGIER MED.		1.028	733	IN	733				2/0 SL
04-02-2013	08⁰⁰ - 10³⁰	ALGECIRAS		1.028	733	OUT	0			MTY	3/0 KGN
18/02/2013	01³⁰ - 05⁰⁰	BISSAU		1.018	733	IN	733			FULL	2/0 SL
22-02-2013	18³⁰ - 23⁰⁰	NOUADHIBOU		1.018	733	OUT	~~733~~ 0			MTY	3/0 KGN
02-03-2013	17⁰⁰ - 21⁴⁵	ALGECIRAS		1.030	733	IN	733			FULL	3/0 KGN
07/03-2013	1145-1615	LEIXOES		1.010	733	OUT	0			MTY	2/0 [illegible]
07/04/2013	1700-2300	TANGIER			733	IN	733			Full	3/0 C. Thyregod
10 04 2013	0300-1900	LISBON		1010	733	OUT	0			MTY	3/0 C. Thyregod
20.05.2013	0100 - 0600	TANGIER		1026	600	IN	600				C/O [illegible]
24/5 - 2013	1140 - 1350	LEIXOES		1010	350	OUT	250				2/0 [illegible]
26 05 2013	0300-1000	ALGECIRAS		1010	250	OUT	0			MTY	3/0 C. Thyregod
05/06/2013	1930 - 2000	PRAIA		1025	550	IN	550				2/0 [illegible]
13/06/2013	0600-0700	BISSAU		1023	000	OUT	0			MTY	3/0 [illegible]
24/6-2013	0100 - 0150	TANGIER		1028	250	IN	250				2/0 [illegible]
01 07 2013	2345 - 2400	ALGECIRAS		1021	80	OUT	170			DISCH	3/0 [illegible]
09/07-13	07:00 ÷ 07:30	MINDELO		1028	120	OUT	50				C/O [illegible]
05/08-2013	04:50-17:08	TANGER		1025	683	IN	733	0,5	15	Gravity	C/O [illegible]
10/8 - 2013	1020 - 1300	LEIXOES		1017	733	OUT	0			Pump + Gravity / Empty	2/0 [illegible]
14/9-2013	0800 - 0950	TANGIER		1026	730	IN	730			FULL BWTS	2/0 [illegible]
22/9-2013	1330 - 1700	LEIXOES		1025	730	OUT	0			MTY BWTS	2/0 [illegible]
28/10-13	PORTSTAY	TANGIER		1.024	733	IN	733			BWTS	2/0 [illegible]
30/10-13	1040-1600	LEIXOES		1.010	733	OUT	0			BWTS	2/0 [illegible]
04/12-13	1400-1800	TANGIER		1.025	625	IN	625			BWTS	2/0 [illegible]
13/12-2013	08:30-10:00	39°38,6N-009°10'3W		1.025	625	OUT	0			MTY BWTS	C/O [illegible]
29/12-13	0350-0507	BISSAU		1.013	200	IN	200			GRAVITY	2/0 [illegible]
08/01-14	2130-2215	NOUADHIBOU	17C	1.013	200	OUT	0			EMPTY BY PUMP	2/0 [illegible]
12/01-14	1730-2115	TANGIER	17	1.025	733	IN	733			Gravity + Pump	C/O [illegible]
14/01-14	16:30-21:00	LISBON	16	1.025	733	OUT	0			MTY	C/O [illegible]
11/02-14	0100-0400	PTM		1.025	733	IN	733			FULL	C/O [illegible]
21/02-14	0900-1200	LEI		1.025	733	OUT	0			MTY	C/O [illegible]

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Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

MAERSK

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: Thurø Mærsk **Ballast Tank No. 4 STB SIDE TANK** **Tank Volume m^3. 733.0**

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m^3	In / Out	Tank Quantity m^3	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
21/8-2012	1903-0212	TANGER-MED		1027	733	IN	733			FULL	2/O [illegible]
20/9-12	1215-1500	LISBON		1027	733	OUT	0			MTY	2/O [illegible]
26/9-12	0935-1600	BISSAU		1010	733	IN	733			FULL	2/O [illegible]
2/10-12	0440-0600	NOUADHIBOU		1010	733	OUT	0			MTY	C/O RLM
15/10-12	1900-2115	ALGECIRAS		1027	733	IN	733			FULL	C/O B.Lay
20/10-12	1640-1900	ALGECIRAS.		1028	733	OUT	0			MTY	3/O Varun.
22/11-12	0650-1725	TANGIER MED		1,028	733	IN	733				C/O B.Lay
22/11-12	1430-1810	LEIXOES		1020	733	OUT	0			MTY	3/O Varun
09/12/12	0915-0950	BISSAU		1015	160	IN	160				3/O Varun
13/12/12	2315-2355	NOUADHIBOU.		1028	160	OUT	0			MTY	3/O Varun
19/12-2012	1200-1600	TANGIER MED		1028	300	IN	300				C/O [illegible]
07/01/2013	12^{30} - 13^{00}	PRAIA		1028	100	OUT	200				2/O S.P
11-01-2013	17^{00} - 18^{15}	BISSAU		1028	200	OUT	0			MTY	3/O KGN
20-01-2013	21^{40} - 00^{10}	TANGIER MED.		1.028	733	IN	733				2/O S.P
04-02-2013	08^{00} - 10^{30}	ALGECIRAS		1.028	733	OUT	0			MTY	3/O KGN
18/02/2013	01^{30} - 05^{00}	BISSAU		1.018	733	IN	733			FULL	2/O S.P
22-02-2013	18^{30} - 22^{45}	NOUADHIBOU		1.018	733	OUT	0			MTY	3/O KGN
02-03-2013	17^{00} - 21^{50}	ALGECIRAS		1030	733	IN	733			FULL	3/O KGN
07/03-2013	1145-1615	LEIXOES		1.010	733	OUT	0			MTY	2/O [illegible]
07/04-2013	1700-2300	TANGER			733	IN	733			Full	3/O C.Thyregod
10 04 2013	0300-1200	LISBON		1.010	733	OUT	0			MTY	3/O C.Thyregod
20-05-2013	0300-0600	TANGIER		1.026	733	IN	733			FULL	C/O [illegible]
29 05 2013	1110-1400	LEIXOES		1025	483	OUT	250				3/O C.Thyregod
26 05 2013	0800-1000	ALGECIRAS		1026	250	OUT	0			MTY	3/O C.Thyregod
09/6-2013	1230-1330	PRAIA		1025	300	IN	300				2/O [illegible]
13/6-2013	0100-0300	BISSAU		1023	300	OUT	0			Empty	2/O [illegible]
24/6-2013	0100-0150	TANGIER		1028	250	IN	250				2/O [illegible]
30/06-2013	1930-2120	ALGECIRAS		1028	~~400~~ 250	OUT	~~400~~ 0			EMPTY	3/O [illegible]
9/08-2013	0450-0950	TANGIER		1025	733	IN	733			FULL - Gravity	3/O [illegible]
10/8-2013	1020-1300	LEIXOES		1017	733	OUT	0			Pump + Gravity / Empty	2/O [illegible]
16/9-2013	0200-0400	TANGIER		1026	730	IN	730			FULL [illegible]	2/O [illegible]

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Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: Thurø Mærsk | **Ballast Tank No. 4 STB SIDE TANK** | **Tank Volume m^3. 733.0**

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m^3	In / Out	Tank Quantity m^3	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
22/9-2013	1300-1700	LEIXOES		1025	730	OUT	0			MTY BWTS	2/O
30/10-13	PORTSTAY	TANGIER		1.024	733	IN	733			BWTS	2/O
30/10-13	1040-1600	LEIXOES		1.010	733	OUT	0			BWTS	2/O
04/12-13	1400-1600	TANGIER		1.025	500	IN	500			BWTS	2/O
13/12-2013	08:30-10.00	39°38.6N-009°40.5W		1.025	500	OUT	0			MTY BWTS	C/O
29/12-13	0350-0503	BISSAU		1.013	300	IN	300			GRAVITY	2/O
08/01-14	2130-2215	NOUDHIBOU	+17°C	1.013	300	OUT	0			EMTY BY PUMP	2/O
12/01-14	1730-2115	TANGIER	+17	1.025	733	IN	733			Gravity + Pump	C/O
19/01-2014	16:30-20:00	LISBON	+16	1.025	733	OUT	0			MTY	C/O
17/02-2014	0100-0400	PTM		1.025	733	IN	733			FULL	C/O
21/02-2014	0900-1200	LEI		1.025	733	OUT	0			MTY	C/O
23/03-2014	1000-1500	TANGIER		1.025	730	IN	730			BY PUMP	3/O
27/03-14	1100-1300	LEIXOES	+15C	1.025	730	OUT	0			BY PUMP EMPTY	2/O

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Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: Thurø Mærsk | **Ballast Tank No. 8 PORT SIDE TANK** | **Tank Volume m^3. 419.0**

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m^3	In / Out	Tank Quantity m^3	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
19/01-2014	1312-1845	ALGECIRAS	16	1025	200	OUT	0			MTY	c/o
28/01-14	1600-2000	MINDELO	24	1.025	400	IN	400			BWTS	c/o
29/01-14	1600-2300	PRAIA	26	1.025	400	OUT	0			MTY BWTS	c/o
14/02-14	1000-1200	31°23.6N - 010°29.4W	19	1.025	419	IN	419			By Gravity	c/o
03/03-14	1400-2200	PRAIA		1.024	419	OUT	0			USING EDUCTOR	3/o
23/03-14	1600-2400	TANGIER		1.025	410	IN	410			BY PUMP	3/o

Master: ____________ Signature: ____________ Date: ____________

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Ballast Log Report

A.P.Moller Group ID:207 - 09/03/2012 - 06 - 60 months

Refer to GSMS procedure 0619 (Mid Ocean Ballast Exchange and Recording of Ballast Operations)

Vessel: Thuro Mærsk | **Ballast Tank No. 8 STB SIDE TANK** | **Tank Volume m³. 419.0**

Date	Time (LMT) From - To	Port or End Position	Temp °C	Specific Gravity	Quantity Pumped m³	In / Out	Tank Quantity m³	Sea Height (Wind - seas + swell) (m)	Water Depth (m)	Remarks	Signature
05/08-2013	0200-0545	TANGIER		1.025	200	IN	200	0,5	15	By Gravity	C/O
07/8-2013	1000-1100	LISBON		1.023	200	OUT	0			by grav	2/O
10082013	1500-1600	LEIXOES		1017	150	IN	150			Pump in	C/O
13082013	2000 2130	ALGECIRAS		1017	100	OUT	0			MTY	3/O
16082013	2100 2226	MINDELO		1017	200	IN	200			Pump in	
20082013	2020 2130	PRAIA		1017	200	OUT	0			MTY	3/O
16/9-2013	0200-0400	TANGIER		1026	415	IN	415			pump	2/O
20/9 2013	0920:1205	LEIXOES		1026	415	OUT	0			MTY	3/O
28/10-13	PORTSTAY	TANGIER		1.024	158	IN	158				2/O
30/10-13	1040-1730	LEIXOES		1.010	158	OUT	0				2/O
29/11-2013	0900-11:00	38°51'N-010°50'W		1.025	419	IN	419	0,5		By Gravity	C/O
13/12-2013	1200-14:00	38°57'N-010°03'W		1.025	419	OUT	0			MTY	C/O
22/12-13	1225-1250	MINDELO		1.024	150	IN	150				2/O
24/12-13	1130-1235	PRAIA		1.023	150	OUT	0				2/O
27/01-14	1600-2000	MINDELO	24	1.025	400	IN	400			BWTS	C/O
29/01-14	1800-2300	PRAIA	26	1.025	400	OUT	0			BWTS	C/O
14/02-14	1000-1200	31°27.6N-010°28.4W	19	1.025	419	IN	419			By Gravity	C/O
04/03-14	1005-1342	PRAIA		1.024	419	OUT	0			MTY	2/O
23/03-14	1600-2000	TANGIER		1.025	410	IN	410			BY PUMP	3/O

Master: Signature: Date:

APPENDIX 4

Detailed data on biological efficacy analyses and physical-chemical parameters in shipboard testing with RayClean

A.4.1 Sample temperature logging during storage and transportation

Table A.4.1.1 Test cycle No. 1. Sample temperature logging from sampling to analysis in the DHI Environmental Laboratory

Test cycle	Sample type	Temperature logging (°C)			Hours from sampling to analysis/incubation initiated
		Storage on location	Transportation to DHI	Storage on DHI	
No. 1	Organisms ≥10 and < 50 µm (Lugol's solution)	7.4 (1.7-13)	15 (13-16)	4.0	Not relevant, samples preserved
	Organisms ≥10 and < 50 µm (CMFDA/FDA)	7.4 (1.7-13)	15 (13-16)	4.0	30 hours
	Organisms ≥10 and < 50 µm (re-growth); Inlet	7.4 (1.7-13)	15 (13-16)	-	34 hours
	Organisms ≥10 and < 50 µm (re-growth); discharge			-	25 hours
	Vibrio cholerae; inlet	7.4 (1.7-13)	15 (13-16)	4.0	41 hours
	Vibrio cholerae; discharge			4.0	32 hours

Table A.4.1.2 Test cycle No. 2. Sample temperature logging from sampling to analysis in the DHI Environmental Laboratory

Test cycle	Sample type	Temperature logging (°C)			Hours from sampling to analysis/incubation initiated
		Storage on location	Transportation to DHI	Storage on DHI	
No. 2	Organisms ≥10 and < 50 µm (Lugol's solution)	2.4 (0.4-5.2)	9.7 (8.2-13)	4.0	Not relevant, samples preserved
	Organisms ≥10 and < 50 µm (CMFDA/FDA)	2.4 (0.4-5.2)	9.7 (8.2-13)	-	34 hours
	Organisms ≥10 and < 50 µm (re-growth); Inlet	2.4 (0.4-5.2)	9.7 (8.2-13)	-	72 hours
	Organisms ≥10 and < 50 µm (re-growth); discharge			-	36 hours
	Vibrio cholerae; inlet	2.4 (0.4-5.2)	9.7 (8.2-13)	-	70 hours
	Vibrio cholerae; discharge			-	34 hours

Table A.4.1.3 Test cycle No. 3. Sample temperature logging from sampling to analysis in the DHI Environmental Laboratory

<table>
<tr><th rowspan="2">Test cycle</th><th rowspan="2">Sample type</th><th colspan="3">Temperature logging (°C)</th><th rowspan="2">Hours from sampling to analysis/incubation initiated</th></tr>
<tr><th>Storage on location</th><th>Transportation to DHI</th><th>Storage on DHI</th></tr>
<tr><td rowspan="6">No. 3</td><td>Organisms ≥10 and < 50 µm (Lugol's solution)</td><td>2.4
(0.4-5.2)</td><td>9.7
(8.2-13)</td><td>4.0</td><td>Not relevant, samples preserved</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (CMFDA/FDA)</td><td>2.4
(0.4-5.2)</td><td>9.7
(8.2-13)</td><td>-</td><td>29 hours</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (Re-growth); Inlet</td><td rowspan="2">2.4
(0.4-5.2)</td><td rowspan="2">9.7
(8.2-13)</td><td>-</td><td>72 hours</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (re-growth); discharge</td><td>-</td><td>31 hours</td></tr>
<tr><td>Vibrio cholerae; inlet</td><td rowspan="2">2.4
(0.4-5.2)</td><td rowspan="2">9.7
(8.2-13)</td><td>-</td><td>70 hours</td></tr>
<tr><td>Vibrio cholerae; discharge</td><td>-</td><td>34 hours</td></tr>
</table>

Table A.4.1.4 Test cycle No. 4. Sample temperature logging from sampling to analysis in the DHI Environmental Laboratory

<table>
<tr><th rowspan="2">Test cycle</th><th rowspan="2">Sample type</th><th colspan="3">Temperature logging (°C)</th><th rowspan="2">Hours from sampling to analysis/incubation initiated</th></tr>
<tr><th>Storage on location</th><th>Transportation to DHI</th><th>Storage on DHI</th></tr>
<tr><td rowspan="6">No. 4</td><td>Organisms ≥10 and < 50 µm (Lugol's solution)</td><td>6.6
(3.0-18)</td><td>14
(12-15)</td><td>4.0</td><td>Not relevant, samples preserved</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (CMFDA/FDA)</td><td>5.8
(3.5-16)</td><td>10
(8.5-14)</td><td>4.0</td><td>63 hours</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (Re-growth); Inlet</td><td rowspan="2">5.8
(3.5-16)</td><td rowspan="2">10
(8.5-14)</td><td>-</td><td>101 hours</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (re-growth); discharge</td><td>-</td><td>53 hours</td></tr>
<tr><td>Vibrio cholerae; inlet</td><td rowspan="2">6.6
(3.0-18)</td><td rowspan="2">14
(12-15)</td><td>-</td><td>101 hours</td></tr>
<tr><td>Vibrio cholerae; discharge</td><td></td><td>53 hours</td></tr>
</table>

Table A.4.1.5 Test cycle No. 5. Sample temperature logging from sampling to analysis in the DHI Environmental Laboratory

<table>
<tr><th rowspan="2">Test cycle</th><th rowspan="2">Sample type</th><th colspan="3">Temperature logging (°C)</th><th rowspan="2">Hours from sampling to analysis/incubation initiated</th></tr>
<tr><th>Storage on location</th><th>Transportation to DHI</th><th>Storage on DHI</th></tr>
<tr><td rowspan="6">No. 5</td><td>Organisms ≥10 and < 50 µm (Lugol's solution)</td><td>6.6
(3.0-18)</td><td>14
(12-15)</td><td>4.0</td><td>Not relevant, samples preserved</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (CMFDA/FDA)</td><td>5.8
(3.5-16)</td><td>10
(8.5-14)</td><td>4.0</td><td>58 hours</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (re-growth); inlet</td><td rowspan="2">5.8
(3.5-16)</td><td rowspan="2">10
(8.5-14)</td><td>-</td><td>96 hours</td></tr>
<tr><td>Organisms ≥10 and < 50 µm (re-growth); discharge</td><td>-</td><td>48 hours</td></tr>
<tr><td>Vibrio cholerae; inlet</td><td rowspan="2">6.6
(3.0-18)</td><td rowspan="2">14
(12-15)</td><td>-</td><td>96 hours</td></tr>
<tr><td>Vibrio cholerae; discharge</td><td></td><td>48 hours</td></tr>
</table>

A.4.2 Physical-chemical parameters

Table A.4.2.1 Measurements of total suspended solids (TSS)

Test cycle	Water type	TSS (mg/L)				
		FR1	FR2	FR3	AVG	STD
No. 1	Inlet	81	88	75	**81**	±6.7
	Control discharge	54	42	44	**47**	±6.2
	Treated discharge	23	21	16	**20**	±3.3
No. 2	Inlet	16	13	13	**14**	±1.9
	Control discharge	7.1	7.2	*	**7.2**	-
	Treated discharge	5.5	7.2	8.2	**6.9**	±1.4
No. 3	Inlet	16	13	13	**14**	±1.9
	Control discharge	7.1	7.2	*	**7.2**	±0.08
	Treated discharge	7.4	6.3	14	**9.2**	±4.1
No. 4	Inlet	7.4	9.8	5.8	**7.7**	±2.0
	Control discharge	13	7.8	8.6	**9.7**	±2.6
	Treated discharge	5.6	8.9	4.8	**6.4**	±2.2
No. 5	Inlet	6.5	6.8	5.3	**6.2**	±0.80
	Control discharge	6.9	7.1	7.1	**7.1**	±0.12
	Treated discharge	10	5.0	4.8	**6.7**	±3.1

FR Field replicate
AVG Average
STD Standard deviation
* Sample lost

Table A.4.2.2 Measurements of particulate organic carbon (POC)

Test cycle	Water type	POC (mg/L)				
		FR1	FR2	FR3	AVG	STD
No. 1	Inlet	0.99	1.4	1.4	**1.2**	±0.22
	Control discharge	1.2	0.73	0.77	**0.90**	±0.26
	Treated discharge	0.63	0.47	0.55	**0.55**	±0.08
No. 2	Inlet	0.21	0.59	0.61	**0.47**	±0.23
	Control discharge	0.36	<0.1	0.32	**0.26**	±0.14
	Treated discharge	<0.1	0.52	<0.1	**0.24**	±0.24
No. 3	Inlet	0.21	0.59	0.61	**0.47**	±0.23
	Control discharge	0.36	<0.1	0.32	**0.26**	±0.14
	Treated discharge	0.48	0.20	0.13	**0.27**	±0.19
No. 4	Inlet	<0.1	<0.1	<0.1	**<0.1**	-
	Control discharge	<0.1	<0.1	<0.1	**<0.1**	-
	Treated discharge	0.13	<0.1	<0.1	**0.11**	±0.02
No. 5	Inlet	<0.1	<0.1	<0.1	**<0.1**	-
	Control discharge	<0.1	<0.1	<0.1	**<0.1**	-
	Treated discharge	<0.1	<0.1	<0.1	**<0.1**	-

FR Field replicate
AVG Average
STD Standard deviation

Table A.4.2.3 Measurements of particulate organic carbon (DOC)

Test cycle	Water type	DOC (mg/L)				
		FR1	FR2	FR3	AVG	STD
No. 1	Inlet	1.1	0.91	0.75	**0.90**	±0.15
	Control discharge	0.74	0.98	0.79	**0.84**	±0.13
	Treated discharge	0.69	0.77	0.75	**0.74**	±0.04
No. 2	Inlet	5.1	2.6	2.5	**3.4**	±1.5
	Control discharge	1.6	2.0	1.7	**1.7**	±0.26
	Treated discharge	6.0	2.4	2.0	**3.5**	±2.2
No. 3	Inlet	5.1	2.6	2.5	**3.4**	±1.5
	Control discharge	1.6	2.0	1.7	**1.7**	±0.26
	Treated discharge	4.1	1.9	2.0	**2.7**	±1.2
No. 4	Inlet	3.2	2.7	1.1	**2.4**	±1.1
	Control discharge	1.1	1.1	0.94	**1.0**	±0.09
	Treated discharge	1.0	1.2	1.5	**1.2**	±0.23
No. 5	Inlet	1.3	1.0	0.93	**1.1**	±0.23
	Control discharge	1.1	1.0	1.0	**1.0**	±0.05
	Treated discharge	1.4	1.2	1.0	**1.2**	±0.20

FR Field replicate
AVG Average
STD Standard deviation

Table A.4.2.4 Concentration of mineral materials (MM). Concentration determined as the difference between the total suspended solids (TSS) and the particulate organic carbon (POC).

Test cycle	Water type	MM (mg/L)				
		FR1	FR2	FR3	AVG	STD
No. 1	Inlet	80	87	73	**80**	±6.7
	Control discharge	53	42	44	**46**	±5.9
	Treated discharge	22	20	16	**19**	±3.2
No. 2	Inlet	16	12	12	**13**	±2.1
	Control discharge	6.7	7.1	-*	**6.9**	-
	Treated discharge	5.4	6.6	8.1	**6.7**	±1.4
No. 3	Inlet	16	12	12	**13**	±2.1
	Control discharge	6.7	7.1	-*	**6.9**	-
	Treated discharge	6.9	6.1	14	**8.9**	±4.3
No. 4	Inlet	7.3	9.7	5.7	**7.6**	±2.0
	Control discharge	13	7.7	8.5	**9.6**	±2.6
	Treated discharge	5.5	8.8	4.7	**6.3**	±2.2
No. 5	Inlet	6.4	6.7	5.2	**6.1**	±0.80
	Control discharge	6.8	7.0	7.0	**7.0**	±0.12
	Treated discharge	10	4.9	4.7	**6.6**	±3.1

FR Field replicate
AVG Average
STD Standard deviation
* TSS sample lost

Table A.4.2.5 Measurements of UV transmittance (UV-T)

Test cycle	Water type	UV-T (%)				
		FR1	FR2	FR3	AVG	STD
No. 1	Inlet	72	67	72	**70**	±2.5
	Inlet 0.2-µm filtered	96	96	97	**96**	±0.67
	Treated discharge	87	89	88	**88**	±0.95
	Treated discharge 0.2-µm filtered	97	96	97	**97**	±0.50
No. 2	Inlet control	80	79	81	**80**	±0.75
	Inlet control 0.2-µm filtered	89	92	91	**91**	±1.4
	Inlet BWMS	45	55	59	**53**	±7.1
	Inlet BWMS 0.2-µm filtered	93	93	92	**93**	±0.80
	Treated discharge	86	87	85	**86**	±0.81
	Treated discharge 0.2-µm filtered	94	94	93	**94**	±0.55
No. 3	Inlet control	80	79	81	**80**	±0.75
	Inlet control 0.2-µm filtered	89	92	91	**91**	±1.4
	Inlet BWMS	79	68	66	**71**	±7.1
	Inlet BWMS 0.2-µm filtered	90	91	92	**91**	±0.67
	Treated discharge	86	85	81	**84**	±2.5
	Treated discharge 0.2-µm filtered	94	92	94	**93**	±0.96
No. 4	Inlet	95	96	*	**96**	-
	Inlet 0.2-µm filtered	93	100	*	**97**	-
	Treated discharge	97	97	96	**97**	±0.56
	Treated discharge 0.2-µm filtered	98	99	99	**98**	±0.64
No. 5	Inlet	92	92	93	**92**	±0.36
	Inlet 0.2-µm filtered	98	96	95	**96**	±1.6
	Treated discharge	90	95	94	**93**	±2.8
	Treated discharge 0.2-µm filtered	99	96	98	**98**	±1.8

FR Field replicate
AVG Average
STD Standard deviation
* Sample lost

A.4.3 Organism size class ≥50 µm

Table A.4.3.1 Enumeration of viable organisms ≥50 µm and sample volumes

Test cycle	Water type	Organisms ≥50 µm							
		FR1		**FR2**		**FR3**		**AVG**	**STD**
		m^3	**org/m^3**	**m^3**	**org/m^3**	**m^3**	**org/m^3**	**org/m^3**	**org/m^3**
No. 1	Inlet	1.5	96,422	1.5	94,167	1.7	85,335	**91,975**	±5,859
	Control discharge	1.2	60,580	1.2	72,240	1.2	82,269	**71,696**	±10,855
	Treated discharge	3.1	9.1	3.1	2.3	3.1	4.2	**5.2**	±3.5
No. 2	Inlet	1.2	5,810	1.2	6,163	1.2	6,629	**6,201**	±411
	Control discharge	1.2	6,083	1.2	4,286	1.2	3,100	**4,489**	±1,502
	Treated discharge	3.3	11	3.2	10	3.2	7.4	**9.4**	±1.8
No. 3	Inlet	1.2	5,810	1.2	6,163	1.2	6,629	**6,201**	±411
	Control discharge	1.2	6,083	1.2	4,286	1.2	3,100	**4,489**	±1,502
	Treated discharge	3.2	3.8	3.1	1.6	3.1	0.32	**1.9**	±1.7
No. 4	Inlet	1.5	5,572	1.5	5,387	1.5	5,641	**5,533**	±131
	Control discharge	1.1	1,299	1.1	2,040	1.1	2,171	**1,837**	±470
	Treated discharge	3.1	0	3.1	0	3.0	0	**0**	-
No. 5	Inlet	1.7	8,217	1.7	6,561	1.7	5,664	**6,814**	±1,295
	Control discharge	1.1	1,133	1.1	897	1.0	1,102	**1,044**	±128
	Treated discharge	3.0	0	3.0	0	3.0	0	**0**	-

FR Field replicate
AVG Average
STD Standard deviation

Table A.4.3.2 Organisms ≥50 µm identified in inlet and control discharge water

Phylum/subphylum	Species	Test cycle			
		No. 1	No. 2 and 3	No. 4	No. 5
Annelida	*Polychaeta* sp.	X	X	X	X
	Polydora sp.	X			
Bryozoa	*Bryozoa* sp.		X		
Chaetognatha	*Chaetognatha* sp.	X			
Cilliophora	*Cilliophora* sp.	X	X		
	Tintinnid sp.		X		
Cnidaria	*Anthozoa* sp.			X	
Crustacea	*Acartia* sp.	X			
	Amphipoda sp.	X			
	Balanus sp.	X	X	X	X
	Carcinus zoea	X			
	Centropages sp.	X			
	Cyclopoida sp.	X			
	Decapoda sp.				X
	Harpacticoid sp.	X	X	X	X
	Isopoda sp.	X			X
	Mysidacea sp.	X			
	Oithona similis		X		
	Oithona sp.	X		X	X
	Oncaea sp.	X		X	X
	Paracalunus sp.	X		X	X
	Pseudocalanus minutus		X		
	Pseudocalanus sp.			X	X
	Temora longicornis				X
	Temora sp.			X	
Dinophyceae	*Dinophyceae sp.*		X		
Echinodermata	*Echinodermata* sp.			X	
Mollusca	*Bivalve* veliger	X	X	X	X
	Gastropod veliger	X	X	X	X
Nematoda	*Nematoda* sp.		X		
Rotifera	*Rotifera* sp.			X	
	Synchaeta sp.		X		
Urochordata	*Larvacea* sp.		X		

A.4.4 Organism size class ≥10 and <50 µm

Table A.4.4.1 Enumeration of viable organisms ≥10 µm and <50 µm by microscopy. The concentrations of motile organisms without chlorophyll are included in the total number of organisms.

Test cycle	Water type	≥10 µm and <50 µm (organisms/mL)									
		Total number of organisms					Motile organisms without chlorophyll				
		FR1	FR2	FR3	AVG	STD	FR1	FR2	FR3	AVG	STD
No. 1	Inlet	284	334	505	**375**	±116	-	-	-	**-**	-
	Control discharge	148	157	142	**149**	±7.6	2.0	5.0	2.0	**3.0**	±1.7
	Treated discharge	4.0	5.0	6.0	**5.0**	±1.0	0	0	0	**0**	-
No. 2	Inlet	100	98	100	**99**	±1.0	-	-	-	**-**	-
	Control discharge	109	119	91	**106**	±14	13	16	12	**14**	±1.9
	Treated discharge	4.0	4.5	5.0	**4.5**	±0.50	0.50	0	0	**0.17**	±0.29
No. 3	Inlet	100	98	100	**99**	±1.0	-	-	-	**-**	-
	Control discharge	109	119	91	**106**	±14	13	16	12	**14**	±1.9
	Treated discharge	2.5	2.0	2.5	**2.3**	±0.29	0	0	0	**0**	-
No. 4	Inlet	83	109	201	**131**	±62	-	-	-	**-**	-
	Control discharge	13	19	18	**16**	±2.9	1.5	1.0	1.5	**1.3**	±0.29
	Treated discharge	1.0	1.5	0	**0.83**	±0.76	0	0	0	**0**	-
No. 5	Inlet	94	129	187	**137**	±47	-	-	-	**-**	-
	Control discharge	20	19	21	**20**	±1.1	0	0	0	**0**	-
	Treated discharge	0.50	0.75	0	**0.42**	±0.38	0	0	0	**0**	-

FR Field replicate
AVG Average
STD Standard deviation

Table A.4.4.2 Determination of algal re-growth by the most probable number (MPN) assay

Test cycle	Water type	Viable algae (organisms/mL)				
		FR1	FR2	FR3	AVG	STD
No. 1	Inlet	>160	>160	>160	**>160**	-
	Control discharge	>160	>160	>160	**>160**	-
	Treated discharge	0.20 (0.03-1.4)	<0.18	0.93 (0.32-2.7)	**0.44**	±0.43
No. 2	Inlet	>160	>160	>160	**>160**	-
	Control discharge	>160	>160	>160	**>160**	-
	Treated discharge	0.20 (0.03-1.4)	<0.18	<0.18	**0.19**	±0.01
No. 3	Inlet	>160	>160	>160	**>160**	-
	Control discharge	>160	>160	>160	**>160**	-
	Treated discharge	0.20 (0.03-1.4)	0.20 (0.03-1.4)	0.45 (0.11-1.8)	**0.28**	±0.14
No. 4	Inlet	>160	92 (29-290)	>160	**137**	±39
	Control discharge	>160	92 (29-290)	>160	**137**	±39
	Treated discharge	0.20 (0.03-1.4)	<0.18	<0.18	**0.19**	±0.01
No. 5	Inlet	>160	160 (54-480)	92 (29-290)	**137**	±39
	Control discharge	160 (54-480)	>160	>160	**>160**	-
	Treated discharge	<0.18	<0.18	<0.18	**<0.18**	-

FR Field replicate
AVG Average
( ) 95% confidence interval
STD Standard deviation

Table A.4.4.3 Algal taxa and species identified in inlet water and their capability for growth under the conditions applied in the algal re-growth assay

Phylum/ subphylum	Species	Test cycle No. 1	Test cycle Nos. 2 and 3	Test cycle No. 4	Test cycle No. 5	Capable of growing in re-growth assay
Bacillariophyceae	*Amphiprora paludosa*		X			
	Amphiprora sp.				X	X
	Asterionellapsis glacialis		X			X
	Chaetoceros affinis	X				X
	Chaetoceros curvisetus	X	X			X
	Chaetoceros debilis		X			X
	Chaetoceros didymus		X			
	Chaetoceros socialis		X			X
	Coscinodiscus radiata		X			X
	Cymbella spp.		X			X
	Ditylum brightwellii		X			X
	Dactyliosen fragilissimus	X				X
	Eucampia zodiacus	X	X	X		
	Guinardia delicatula	X				X
	Lauderia annulata	X	X			X
	Leptocylindrus danicus	X	X			X
	Melosira nummuloides		X			X
	Nitzschia longissima/Cylindrotheca closterium	X	X			X
	Nitzschia paleacea	X				X
	Nitzschia sp.			X	X	X
	Odontella mobiliensis	X	X			X
	Paralia sulcata	X				X
	Pleurosigma elongatum	X	X			X
	Pleurosigma sp.			X		X
	Porosira glacialis		X			X
	Porosira stelliger	X				
	Pseudonitzschia spp.	X				X
	Rhizosolenia delicatula		X			
	Rhizosolenia styliformis	X				X
	Skeletonema costatum		X			X
	Stephanopyxis turris		X			X
Chlorophyceae	*Tetraselmis* sp.	X				X
Dinophyceae	*Alexandrium* sp.			X		
	Gymnodinium aureolum				X	
	Gymnodinium spp.			X		X
	Gyrodinium spirale		X			X
	Heterocapsa triquetra			X	X	X
	Prorocentrum micans		X			X
	Protoperidinium brevipes	X				

A.4.5 Organism size class <10 µm (bacteria)

Table A.4.5.1 Enumeration of enterococci

Test cycle	Water type	Enterococci (CFU/100 mL)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
No. 1	Inlet	65	43	32	-	-	-	-	-	-	**47**	±17
	Control discharge	21	21	32	-	-	-	-	-	-	**25**	±6.4
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
No. 2	Inlet	32	98	690	-	-	-	-	-	-	**273**	±362
	Control discharge	110	130	98	-	-	-	-	-	-	**113**	±16
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
No. 3	Inlet	32	98	690	-	-	-	-	-	-	**273**	±362
	Control discharge	110	130	98	-	-	-	-	-	-	**113**	±16
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
No. 4	Inlet	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Control discharge	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
No. 5	Inlet	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Control discharge	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-

CFU Colony-forming units
FR Field replicate
AVG Average
STD Standard deviation

Table A.4.5.2 Enumeration of *E. coli*

Test cycle	**Water type**	***E. coli* (CFU/100 mL)**										
		FR1	**FR2**	**FR3**	**FR4**	**FR5**	**FR6**	**FR7**	**FR8**	**FR9**	**AVG**	**STD**
No. 1	Inlet	590	540	120	-	-	-	-	-	-	**417**	±258
	Control discharge	170	230	180	-	-	-	-	-	-	**193**	±32
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-
No. 2	Inlet	370	290	3,900	-	-	-	-	-	-	**1,520**	±2,062
	Control discharge	440	780	850	-	-	-	-	-	-	**690**	±219
	Treated discharge	53	110	110	<10	<10	<10	10	10	10	**37**	±44
No. 3	Inlet	370	290	3,900	-	-	-	-	-	-	**1,520**	±2,062
	Control discharge	440	780	850	-	-	-	-	-	-	**690**	±219
	Treated discharge	<10	<10	10	<10	<10	<10	<10	10	10	**<10**	-
No. 4	Inlet	53	10	10	-	-	-	-	-	-	**24**	±25
	Control discharge	10	160	170	-	-	-	-	-	-	**113**	±90
	Treated discharge	52	76	52	<10	76	220	150	250	76	**107**	±82
No. 5	Inlet	21	<10	<10	-	-	-	-	-	-	**14**	±6.4
	Control discharge	<10	<10	<10	-	-	-	-	-	-	**<10**	-
	Treated discharge	<10	<10	<10	<10	<10	<10	<10	<10	<10	**<10**	-

CFU Colony-forming units
FR Field replicate
AVG Average
STD Standard deviation

Table A.4.5.3 Enumeration of *Vibrio cholerae*

Test cycle	Water type	*Vibrio cholerae* (CFU/100 mL)										
		FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	AVG	STD
No. 1	Inlet	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Control discharge	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Treated discharge	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-
No. 2	Inlet	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Control discharge	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Treated discharge	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-
No. 3	Inlet	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Control discharge	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Treated discharge	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-
No. 4	Inlet	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Control discharge	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Treated discharge	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-
No. 5	Inlet	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Control discharge	Absent	Absent	Absent	-	-	-	-	-	-	-	-
	Treated discharge	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-

CFU Colony-forming units
FR Field replicate
AVG Average
STD Standard deviation

APPENDIX 5

Test report from Statens Serum Institut (SSI) for verification of *Vibrio cholerae.* Inlet, control discharge and treated discharge water from shipboard test cycles Nos. 4 and 5

DANAK
Akk.nr. 397

10. februar 2014

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Dyrkning for *Vibrio o.a.*

SSI nr.	Dit nr.	Modtaget	Afsluttet	Resultat
H28263	B-1-14-5	05/02/2014	10/02/2014	Vækst af *Vibrio alginolyticus*
H28265	B-1-14-19	05/02/2014	10/02/2014	Vækst af *Vibrio alginolyticus*
H28269	B-1-14-25	05/02/2014	10/02/2014	Vækst af *Vibrio alginolyticus*
H28271	B-1-14-45	05/02/2014	10/02/2014	Vækst af *Vibrio alginolyticus*
H28272	B-1-14-55	05/02/2014	10/02/2014	Vækst af *Vibrio alginolyticus*
H28273	B-1-14-70	05/02/2014	10/02/2014	Vækst af *Vibrio alginolyticus*
H28274	B-1-14-94	05/02/2014	10/02/2014	Vækst af *Vibrio alginolyticus*

Regning fremsendes separat.

Med venlig hilsen

På vegne af
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APPENDIX 6

Quality control and quality assurance for performance evaluation in shipboard testing with RayClean

Quality control and quality assurance	Description	Overall responsible
Quality control, data from laboratory analyses and database entries	All results related to samples and laboratory analyses are stored in relevant databases. All data entries in databases have been quality controlled. Laboratory records are filed in the DHI archives.	Last data entry 2014.02.06 Camilla Hedberg
Quality control, onsite data from shipboard testing	Onsite data records are filed in the DHI archives.	Filing of onsite data records 2014.04.02 Camilla Hedberg
Quality control, interim reports and final report	All data related to a specific test cycle have been reported in interim test cycle reports except for test cycles Nos. 4 and 5, which were only reported in the final report. Reports have been written by members of the project team upon completion of quality control of all data sets. All data sets in interim test cycle reports and final report have been quality controlled.	Quality control interim reports and final report 2014.04.02 Camilla Hedberg, Michael Andersen
Quality control, final report	Data and data interpretation related to the present performance evaluation have been quality controlled, and all data are truly and accurately presented in the final report.	Quality control, final report 2014.10.13 Torben Madsen
Quality assurance, final report	The performance evaluation has been conducted in accordance with the QMP, QAPP, the Test Plan and the DHI SOPs. The performance evaluation was conducted in compliance with the IMO G8 guidelines and ETV protocol.	Quality assurance of project 2014.10.17 Louise Schlüter